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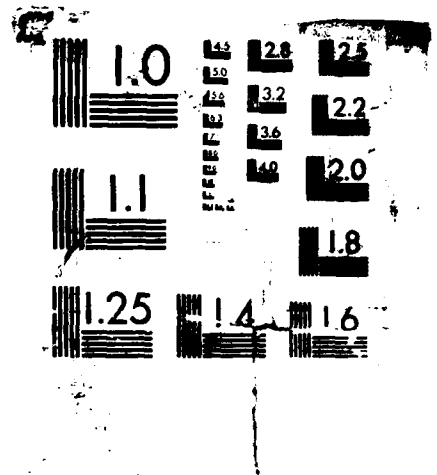
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COMPILATION OF 1986 ANNUAL REPORTS
OF THE NAVY ELF COMMUNICATIONS SYSTEM
ECOLOGICAL MONITORING PROGRAM

Volume 3 of 3 Volumes: TABS H-J

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July 1987

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Washington, D.C. 20363-5100

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19. Abstract (Continued)

H. Aquatic Ecosystems

Michigan State University

Burton, T.M.; Stout, R.J.; Taylor, W.W.; Muzzall, P.M.; Oemke, M.P.;

Glosser, R.; O'Malley, M.; Whelan, G.

I. Wetland Studies

University of Wisconsin-Milwaukee

Stearns, F.; Guntenspergen, G.; Keough, J.; Wikum, D.

J. Bird Species and Communities

University of Minnesota-Duluth

Niemi, G.J.; Hanowski, J.M.; Blake, J.G.



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FOREWORD

The U.S. Navy is conducting a long-term program to monitor for possible effects from the operation of its Extremely Low Frequency (ELF) Communications System to resident biota and their ecological relationships. The program is being implemented by IIT Research Institute (IITRI) under contract to the Space and Naval Warfare Systems Command (SPAWAR). IITRI provides engineering support and coordinates the efforts of investigators. Monitoring projects are being carried out through subcontract arrangements between IITRI and study teams at several universities.

This is the fifth compilation of annual reports prepared by university study teams. Each report chronicles the data collection and analysis activities for a monitoring project during 1986. As in the past, each report has been reviewed by four or more scientific peers. Investigators have considered and addressed reviewer critiques prior to providing their report for printing. Reports have been printed from original copies without change or editing by either IITRI or SPAWAR.

The 1986 compilation is one of a series that documents the activities of the Ecological Monitoring Program since its inception in 1982. Other reports document engineering support and summarize the progress of the Program. Previous reports provide information on the background, overall design, and early development of the Program. All of these reports have been provided to the National Technical Information Service for unlimited distribution. The results of monitoring activities have also been presented at scientific meetings or as journal articles.

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- E. Report Identification Number AE-058
- F. Prepared by:
1. Thomas M. Burton, Professor
Principal Investigator, Departments of Zoology and
Fisheries and Wildlife
 2. R. Jean Stout, Research Associate Professor
Co-Principal Investigator, Department of Entomology
 3. William W. Taylor, Associate Professor
Co-Principal Investigator, Department of Fisheries
and Wildlife
 4. Patrick M. Muzzall, Associate Professor
Department of Natural Science
 5. Mark P. Oenke, Research Associate
Department of Zoology
 6. Ron Glosser, Field Technician II
Department of Entomology
 7. Michael O'Malley, Field Technician II
Department of Zoology
 8. Gary Whelan, Field Technician II
Department of Fisheries and Wildlife
- H. Approved by: 
Howard G. Grider, Director
Contract and Grant Administration

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IV. SUMMARY

The following is a summary of the data base collected from 1 November 1985 to 31 October 1986 summarized by the elements listed in the 1985-86 work plan. Some previous data are included where needed to complete overall trend analysis.

Element 1 -- Conduct Ambient Monitoring Program

All automatically monitored data from 1985 and 1986 have been summarized and daily averages for most of the growing season are available for both years. These data have subsequently been used in correlations with biotic data.

Ambient monitoring data are available to fulfill the objectives for this element. These data show that FCD and FEX are very comparable sites with only minor differences from site to site. These data also demonstrate the excellent water quality of the Ford River. These data have been used in the biotic monitoring program with correlations between periphyton, insects, and fish and appropriate ambient monitoring data having been examined. The correlations between various physical and chemical parameters reported in this element will be useful in interpreting the results of correlations between ambient monitoring and biotic parameters. The background data established by this procedure will also allow us to detect any shifts in water quality that might occur from unexpected pollution events or land use changes.

Element 2 -- Monitoring of Species Composition, Numbers, Diversity, Biomass Production, Cell Volume and Chlorophyll a/Phaeophytin a Production for Periphyton.

1. Chlorophyll a

Annual patterns for chlorophyll a standing crop and accrual were characterized by considerable year-to-year variability. The only consistency between data for 1986 and data for the two previous years was a July-August peak and winter lows. The summer peak varied in magnitude between years but always occurred. In 1986, no site differences were detected ($p < 0.05$) between FCD and FEX for chlorophyll a. Differences had occurred in 1983 and 1984 but not in 1985. This lack of intersite difference in 1985 and 1986 coupled with use of 3-way ANOVA analyses or the new BACI technique described in this report suggest that this parameter can be used to detect differences which may occur between sites once ELF exposure begins.

2. Organic Matter

Organic matter standing crop and accrual rates showed considerable year to year variability as had chlorophyll a. These parameters have consistently been characterized by no significant differences between sites since the start of the project in 1983. This trend continued in 1986. The only year to year consistency has been a July-August peak in standing crop and accrual rates.

3. Chlorophyll a to Phaeophytin a Ratios

This ratio continued to vary widely throughout the year in 1986. It is not a useful parameter for detection of ELF effects.

4. Diatom Cell Density

Diatom cell density continued to be characterized by no statistical differences between sites ($p < 0.05$). Trends in cell density do not include a July-August peak. Instead, individual numbers tend to be high throughout the summer with some tendency towards a June peak. Conversely, individual cell volume tends to be higher in the winter while numbers are low.

5. Species Diversity and Evenness

Diatom species diversity and evenness were not significantly different between FEX and FCD in 1986 ($P < 0.05$) continuing the trends established in 1983, 1984 and 1985. Annual trends continued to be characterized by high diversity and evenness during winter with lower values during the summer.

6. Total Biovolume and Individual Cell Volume Studies

Individual cell volumes of the 20 dominant diatom species were not significantly different ($P < 0.05$) between the experimental and control sites. Total biovolume was significantly larger at the control site than at the experimental site as had been true in 1985.

7. Before and After, Control and Impact (BACI) Analyses

Stewart-Oaten *et al.* (1986) developed this procedure for just the type of analyses we are conducting. We illustrate the procedure by comparing 1983-84 ("before") data for *Cocconeis* to 1984-85 ("after") data. No significant changes between years were detected. This procedure will be used for both species and community level analyses in our final report.

8. Correlation with Environmental Variables

Correlation matrices were calculated using variously transformed data. No single transformation appears to give an overall better correlation than does untransformed data. However, certain transformations appear to enhance correlations between biological and physical variables while other transformations enhance correlations between the various biological parameters. Stepwise regressions were also calculated in 1986 and continued to emphasize the importance of water temperature in explaining variance in much of the biological data.

9. Photosynthesis-Respiration Studies

Net production, respiration, and gross production of the community on rock surfaces did not differ significantly ($P < 0.05$) between FEX and FCD in either 1984, 1985 or 1986. These measurements appear to offer a precise means of detecting ELF effects on community metabolism.

Element 3 — Effects of Insect Grazer Populations on Periphyton Communities

The 1985 studies demonstrated the feasibility of using streamside flow through channels and tiles colonized in the river to conduct grazer studies. These studies also indicated that Glossoma nigrum, a caddisfly grazer, was capable of causing species and diversity shifts in the diatom community even though these shifts were not reflected in chlorophyll a or organic matter standing crop data. The species composition shift included a shift towards increased dominance by Achnanthes affinis and decreased dominance by Cocconeis placentula. The 1986 studies were conducted simultaneously at the control (FCD) and experimental (FEX) sites. There were major differences in initial standing crop of chlorophyll a between sites. However, grazing pressure caused no significant shift in standing crops of either chlorophyll a or organic matter. Thus, 1985 data were corroborated. Species counts had not been completed at the time of report preparation. Alternate grazers were also examined. Preliminary experiments indicate that a small limpet may be a very efficient grazer which could be used in future comparisons of ELF effects between sites.

Element 4 — Species Richness and Biomass of Stream Insects from Artificial Substrates in Riffles

Taxon diversity (H') and evenness (J') from 1983 to 1984 were highly correlated with one another. Both parameters had their highest values in the summer months and their lowest values during the winter months. High chironomid abundances greatly affected H' and J' , and are highly correlated with those two parameters. When chironomids were excluded from benthic insect analyses, correlation coefficients for J' with respect to H' were lower — especially at FCD, which is the site containing high numbers of chironomids relative to other species abundances.

Distinct seasonal patterns were found for insect total biomass over a four year period. These patterns were highly correlated with diatom densities and water temperatures at FEX and FCD combined. Changes in biomass values over seasons for the functional feeding groups, collector-gatherers, collector-filter feeders, and predators were highly correlated with diatom densities. Shredder biomass values were not. These seasonal patterns will continue to be investigated, using additional ambient monitoring data.

Biomass values, when coupled with numerical abundances of certain taxa, were low in variance over time. The following taxa showed consistent size class patterns (MDW/IND) from 1983 to 1986 at both sites: Chironomidae, Paraleptophlebia mollis, Ephemerella invaria, E. subvaria, and Optioservus sp. They will continue to be monitored. Because Optioservus is not a univoltine genus but both adults and larvae are found in samples, separate analyses as to adult/larval ratios will be performed. MDW/IND data for this genus is less reliable than those data for other species, given the fact that there is generation overlap. Glossosoma and Protophila will also be added to the list of taxa to be followed. Their total numbers followed diatom density, water temperature, and total insect biomass over the years. Next year, the MDW/IND values will be presented.

From February through September of 1986 we collected 10 replicates per site at each collection date. After September, the replicate number was reduced to seven. However, time constraints have been such that usually 5-7 replicates are processed.

Element 5 — Movement Patterns of Selected Aquatic Invertebrates

Naïads of O. colubrinus travelled in a downstream direction for short distances over time at FEX and FCD. Their lateral movements were related to flow patterns at each of the sites. Percent recapture success was sufficiently high (usually over 40%) to make us rather confident that we are monitoring actual movement patterns of the predator. The only difference between the FEX and FCD with respect to movement patterns was that animals tended to move farther at FCD. This is likely related to the higher mean velocities at that site. Owing to the numerical dominance, markability and sessile behavior of these animals, they are appropriate for movement pattern studies. Further, the repeatability of the results indicates that if effects of ELF alters movements of these rather sessile animals, we will be able to detect those changes.

Element 6 — Leaf Litter Processing

Leaf processing rates (-k) were not significantly different for 1982-1984, 1985 and 1986. H' and J' values were also similar. Numbers of species (S), however, remained higher over time in 1984 as compared with 1982-1983 and 1985-1986 data. Percent dominance of chironomids on leaves was similar for all the studies. One shredder, B. flavifrons, showed similar numerical and size-class patterns in 1982-83 and 1984. In 1985, both numbers were lower and size class changes were not as distinctive as in previous years. The MDW/IND values for E.invaria, a collector-gatherer, and for I.transmarina, a predator, were similar in 1984 and 1985 (1984 was the first year they began being monitored.) C.V. Values, except for total biomass and functional feeding group biomass, were below 18%.

Element 7 — Fish Community and Abundance

1. Species Composition

Thirteen species from five orders and ten families were collected at FEX in 1986. This represents a net decrease of two families and no change in the number of species or orders from previous years. Seventeen species from ten families and five orders were collected at FCD in 1986 with a decline of one species, family and order from previous years. Overall, the species composition was similar at the two sites with the only changes seen in the rare species.

2. Species Abundance

Numerically and by biomass the fish community was dominated by five species. Numerically, common shiners and creek chubs made up over 45% of the catch at both sites. Common shiner catch was the least variable, and

white sucker and burbot catches were the most variable. By biomass, white suckers and brook trout were the dominant species, making up 45% of the catch at both sites. Brook trout and burbot catch in biomass was the most variable. Catch in biomass was more variable from year to year than catch in number. Overall, the fish species composition was similar from site to site and from year to year.

Species diversity declined at both sites in 1986 from previous values, although this trend was only significant at FEX. No significant differences were found between sites and the diversity values ranged between 1.6 to 2.2.

3. Catch Statistics

Catch rates (catch per day) were variable for all species and were seasonally dependent. Catch rates for common shiners, creek chubs and white suckers all increased from 1984-86 at FEX. No other trends were seen at FEX. Only brook trout showed a trend (-) in catch rates at FCD. Brook trout, creek chubs and white suckers all demonstrated similar catch rates at both sites and the differences can be attributed to increased habitat heterogeneity at FCD.

The mean length of most species showed no consistent year to year trends at either FCD and FEX, and fish at FCD were significantly larger for all species except for burbot. Brook trout did decline in length in 1986 from previous years at both sites.

4. Fish Community Mobility

Most fish non-salmonid species with adequate sample sizes demonstrated site to site movement with most species showing a non-marking site recapture rate of 20%. Recapture percentages were similar to previous years except for a decline in creek chub recaptures. Overall, site to site ^{comparisons} were lower in 1986 than the previous years which may be attributed to significantly lower discharge in 1986.

5. Individual Species Analyses

Age, growth and condition factor analysis using common shiners, creek chubs, northern pike and white suckers was initiated as a section of this element in 1986 with the premise that these factors are good indicators of the fish stress. Preliminary growth analysis using scales indicated that common shiners and creek chubs show better than average growth when compared to literature values. White suckers and northern pike both displayed poor growth when compared to literature values. Statistical analysis of yearly trends, and the effect of population size and abiotic factors on growth will be completed when the 1984-1986 scales are completed. Fish condition was examined using relative condition factors. Standard weight formulas were derived for common shiners, creek shubs and white suckers from literature data. Common shiner condition was above the species average in each year. Creek chubs and white suckers demonstrated below species average condition ($Wr=80-96$). Creek chubs and white suckers condition factors declined from 1983-1986 by 5%. Common shiner condition showed a cyclic trend with a modulation of 7% per year.

Element 8 — Brook Trout Movement

1. Movement Patterns and Rates

Brook trout catches peaked in spring-early summer at all sites except FCU. The peak occurred in June in 1984 and in July in 1985 with the movement in an upstream direction. Peak catches of 1984 and 1985 were not repeated in 1986. Brook trout movement appeared to be caused by mean water temperatures exceeding the optimal growth temperature (16°C) and the rate of this increase which is related to acclimation time. Low groundwater discharge and river flow volumes also may create thermal barriers to movement. Brook trout ($>190\text{ mm}$) move from FEX and FCD upstream to the TM site based on a total of 520 tagged and branded fish. In 1984 and 1985, TM was chosen over FCU on the basis of mean temperature being closer to optimal growth temperature. Recapture rates were consistent from 1984 to 1985 with no movement found in 1986. Movement rates were found to range between 1.1 to 5.0 km/day. Ranges from FEX to TM were similar between 1984 and 1985 with no catches between these sites in 1986. Brook trout movement rates were greater in 1985 than 1984 from FCD to TM with no movement detected in 1986. Angler tag return data verified the above movement rates indicating the fish move at a consistent measurable rate upstream.

2. Population Analysis

Michigan Department of Natural Resources conducted 4 electrofishing surveys at two sites on the Ford River. The brook trout density at FSI in June 1985 was 269 ± 47.5 per ha with a biomass of 2.35 kg/ha. Most of these fish were YOY and yearling fish with very low densities of adult fish. Trout densities at FCD were estimated at 60.7 fish/ha (biomass = 1.28 kg/ha) in June 1985, 15.7 fish (biomass = 0.31 kg/ha) in August 1985 and 0 fish in August 1986. These densities are very low when compared to literature values and are probably indicative of the variable conditions of the Ford River. These data also indicate that a large percentage of the population moves out of the lower river (FCD site) in the spring movement period.

3. Brook Trout Age, Growth and Condition

Age and growth analysis using scales indicated that the brook trout in the Ford River exhibit average or better growth when compared to literature values based on a preliminary analysis of 1983 and 1984 fish. Brook trout length at age 1 was approximately 95 mm, at age 2 was approximately 190 mm and at age 3 was approximately 280 mm. Statistical analysis of this data is in progress and will be reported in the next report. Brook trout condition was examined using relative weight condition factors (W_r). A standard weight formula was calculated from 45 literature populations for use in this analysis. Ford River brook trout demonstrated average to below average condition when compared to the species average (W_r 89 - 101). Condition factors declined from 1983 to 1986. Statistical analysis of this data is in progress and will be reported in the next report.

Element 9 — Parasite Loads of Selected Fish Species

The parasite faunas of longnose dace between sites were comparable taxonomically and in species numbers. This was also true for the parasite faunas of sculpins between sites. The parasite faunas of each fish species at each site were composed primarily of larval parasites that mature in fish eating birds and fish. Of the helminths found, only Rhabdochonacandensis mature in dace while Crepidostomum ~~sp. att~~ Rhabdochonacotti mature in sculpins. Epistylis sp. was the most common external parasite of dace and sculpins. Quantitatively, Posthodiplostomum m. minimum metacercariae and Tetracotyle metacercariae were the most common helminths of dace and sculpins, respectively. Significant differences in the prevalence and mean number of the parasite species were not found between sexes of either host species. In dace, the number of P. minimum, Neascus sp., and R. canadensis at all sites, and the number of R. cotti in sculpins at FEX and FCD significantly increased as host length increased. The number of Diplostomum sp. significantly decreased at all sites and the number of Tetracotyle sp. and R. cotti in sculpins, and P. m. minimum and Neascus sp. in dace decreased in mean numbers and prevalences from the upriver to the downriver sites. The mean number of R. canadensis was highest in dace from FCU and the prevalence of this nematode species decreased from the upriver to the downriver sites. The high overall mean Brillouin's diversity indices of counted helminths for both infected dace and sculpins indicate that these fish species from the three sites in the Ford River have very diverse helminth communities. Seasonal trends in infection rates for the parasites were not observed or were not consistent between years. Because of this and the extreme variation in the parasite data, longnose dace and sculpin age cohort analyses for the three most common helminth species in both fish species are in the process of being analyzed to determine if infection trends exist.

V. PROJECT RATIONALE, AND APPROACH

Our research plan is directed at determining the effects of extremely low-level, long term electromagnetic fields (ELF) and gradients produced by the ELF Communications Systems on aquatic plant and animal life. The integrated approach we have taken is to combine the major interrelated and interactive components of aquatic systems (i.e., periphytic algae, aquatic insects, and fish) and to monitor sensitive life history events and community processes critical to the basic structure and function of stream ecosystems. These include: periphyton and stream invertebrate colonization, migration, diversity, trophic level changes in density and biomass, as well as primary productivity; organic matter processing by macroinvertebrates; dynamics of fish population growth, reproduction, and survival; fish behavior including movement patterns of homing and migration, and fish pathogen and parasite loads. Since many of these processes and events are mutually dependent on one another and the interactions are complex, we feel that a holistic approach with a multi-disciplinary effort is imperative.

In our original research plan, we proposed an integrated study of stream ecosystems involving three aquatic components for monitoring the potential effects of ELF. These components were: 1) periphytic algae; 2) aquatic insects; and 3) fish. The design incorporated studies of ecosystem properties with studies of behavior and biology of individual species so that any effects of ELF would be quantified at the population, community and ecosystem levels.

We selected stream ecosystems as representative aquatic ecosystems rather than lakes or marshes because: (1) upstream-downstream paired plots on the same system would provide less variability than between lake comparisons; (2) migratory behavior was more likely to be important in stream organisms; and (3) our local expertise and interests were oriented more toward stream ecology.

We planned to test the effects of ELF on stream ecosystems by using paired "plots" design of selected sections of a chosen stream. Specific control and experimental sites were to be selected after the final ELF cable corridors were established. We planned to select a stream section containing pools and riffles in an area of forest just upstream of the cable corridor with maximum exposure to extremely low frequency electromagnetic radiation (ELF). This section was to be compared to a physically similar site (with regard to depth, width, flow rates, canopy cover, etc.) on the same stream far enough from the ELF. The two stream sections constituted our paired "plot" design. Thus, we planned to have two plots of intensive stream studies: a control site FCD (Fig. A) and an experimental site FEX (Fig. A) at the cable corridor. We expected these studies to continue for at least 3 years of preconstruction background data collection followed by at least 3 years of post construction data collection.

For each site, we planned to continuously monitor stream velocity and water depth so the discharge could be calculated. Water and air temperatures, dissolved oxygen, pH, and solar radiation at the water

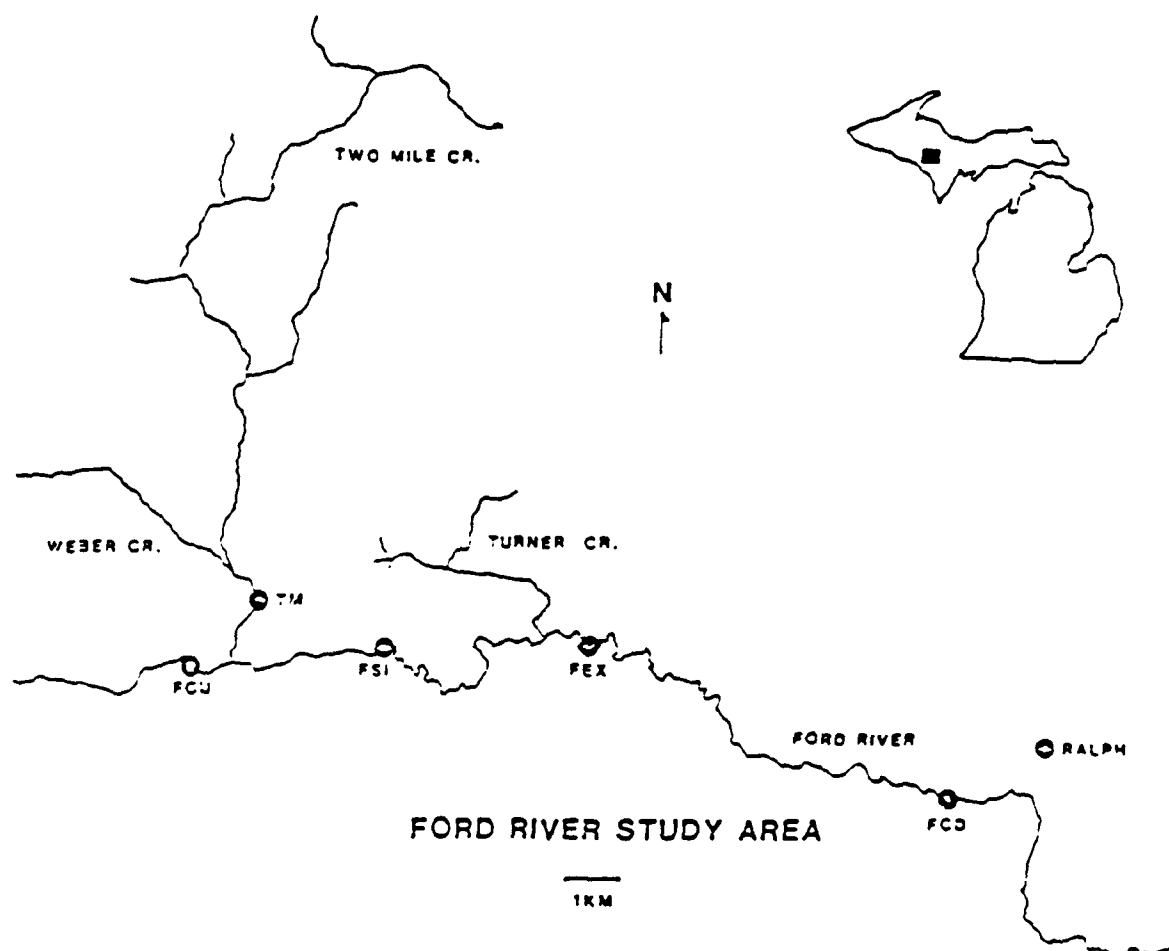


Figure 1 A. Map of the Ford River study sites for the Aquatic Studies Group.

surface and at the stream bottom were also to be continuously monitored. We planned to sample all other chemical parameters required in the RFP as detailed in the work plan submitted for 1985/86.

The data generated from this research should: (1) determine whether the ELF communications System affects aquatic plant and animal life in stream systems; and (2) contribute to a better understanding of stream organism processes which will help clarify a number of important aspects of current conceptual models of stream ecosystem structure and function.

VI. OVERALL OBJECTIVES AND SPECIFIC TASK OBJECTIVES

OVERALL OBJECTIVE

Our major objective in this study is to determine the effects of low level, long term electromagnetic fields and gradients produced by the ELF Communication System on aquatic plant and animal life in streams. The study will incorporate studies of ecosystem properties with studies of behavior and biology of individual species so that any effects of ELF will be quantified at the population, community and ecosystem level.

SPECIFIC TASK OBJECTIVES

A. Periphytic Algal Studies

The objectives of the periphytic algal studies are:

- (1) to quantify any changes in species diversity, algal density, and chlorophyll a that occur as a result of ELF electromagnetic fields;
- (2) to quantify any changes in primary productivity that might occur as a result of ELF; and
- (3) to monitor algal cell volume and chlorophyll a to phaeophytin a ratio, thereby providing an index to physiological stress of periphytic algal cells that might occur as a result of ELF electromagnetic fields.

B. Aquatic Insect Studies

The objectives of the studies of aquatic insects are:

- (1) to quantify any changes in organic matter processing rates that occur as a result of ELF;
- (2) to quantify changes in species richness, individual abundances, and species diversity of the aquatic insect communities associated with leaf packs and inorganic stream bottom substrates;
- (3) to quantify changes in upstream-downstream movements of selected aquatic insects that might occur as a result of ELF; and
- (4) to quantify trophic, behavioral, and community level changes in selected species of aquatic insects from an array of functional feeding groups (grazers, collectors, etc.).

C. Fish Studies

The objectives of the studies of fish are:

- (1) To quantify any changes in the seasonal movement patterns and abundance of the mobile fish community that occur as a result of ELF;
- (2) To quantify any changes in the rate of brook trout movement through the ELF corridor that occur as a result of ELF electromagnetic fields;
- (3) To quantify any changes in the rates of parasitism of one mobile species (longnose dace) and one sessile species (mottled sculpin) of fish that occur as a result of ELF.

VII. PROGRESS BY WORK ELEMENT

Element 1 - Conduct Ambient Monitoring Program

Changes from workplan - None.

Objectives

The objectives of this work element are:

- (1) to provide the background data on physical and chemical parameters needed to correlate observations on biological community dynamics with environmental parameters; and
- (2) to monitor stream chemistry and physical factors to determine whether or not observed changes in community structure are related to water quality changes rather than potential ELF radiation induced changes.

Rationale

The chemical and physical factors selected for study are known or suspected to be important factors that may control or influence growth, community structure, or community dynamics of periphyton, insects, and fish. Correlating these variables with biological data may ultimately be useful in predicting the effects of these environmental parameters on the biotic community. Thus, they may be useful in separation of background environmental variability from effects induced by extremely low frequency radiation (ELF). Even though many of these variables may not presently correlate with biological data, unexpected large shifts could lead to dramatic changes in the biotic community. Thus, a second goal of the monitoring program is to document the presence or absence of shifts in physical or chemical variables that could occur if some perturbation such as an unexpected discharge of a pollutant were to occur.

Materials and Methods

Ambient monitoring stations were installed at the experimental site (FEX) and at the control site (FCD) on April 17, 1986 and were operated until October 3, 1986. The data collected for 1986 continued the data collection started in July, 1983 (July through October, 1983) and continued from April 10-12, 1984 through October 22, 1984 and from April 29-30, 1985 through October 24, 1985.

The stations automatically logged on Omnidata data pods (models DP211 and DP213) the following parameters:

- (1) solar radiation (a) above the surface of the stream and (b) solar radiation below the water surface about 15 cm above the stream bottom in riffle to pool transition areas using Li-Cor model LI-192SB underwater quantum sensors;
- (2) dissolved oxygen using Leeds and Northrup model 7932 portable dissolved oxygen meters with general purpose submersible probes;
- (3) pH using the Altex (Beckman) Monitor II System with specially built long term gel-filled submersible pH probes from Fisher Scientific;

- (4) water depth using Leupold and Stevens model F strip chart recorders; and
- (5) air and water temperature using thermistors.

The pH probes were calibrated twice per week with pH 7 and 10 buffers and were routinely checked against a separate laboratory pH meter to insure accuracy. The dissolved oxygen meters and probes were calibrated twice per week with the azide modification of the Winkler procedure (APHA 1980). Air and water temperature and stream depth were also manually determined twice per week and recorded. After data were recorded for 2-3 weeks on the Omnidata data pods the data were read onto diskettes using the Omnidata Model 217 reader and an Apple II plus computer. Much of these data are archived and are available for use as needed.

In addition to the manual determinations of pH, dissolved oxygen, water depth, and air and water temperature twice per week as described above, samples were taken twice per week for turbidity and suspended and dissolved solids analyses. Once per week, alkalinity, hardness, and conductivity were determined. Nutrient samples (total and molybdate reactive P, $\text{NO}_3\text{-N}$, $\text{NO}_2\text{-N}$, $\text{NH}_4\text{-N}$, total Kjeldahl-N) were taken twice per week during the field season and frozen immediately for later analysis. Samples were also taken on the same schedule for chloride (samples frozen) and dissolved silicate (samples refrigerated). During winter months (November to April), all sampling was reduced to once every four weeks, and ambient monitoring stations were removed from the field and stored.

All chemical analyses followed procedures outlined in Standard Methods (APHA 1980) or approved techniques of the U.S. Environmental Protection Agency (U.S. EPA 1979b). The quality control program recommended by the U.S. Environmental Protection Agency (U.S. EPA 1979a) was initiated at the start of the field season in 1983. Laboratory nutrient analyses (N, P, Si, etc.) were conducted using auto-analyzer techniques as outlined in the U.S. EPA manual (1979b).

Stream discharge was determined from stage (water level) - discharge relationships determined for each station using Gurley pygmy or Price-type current meters using the velocity area technique (Gregory and Walling 1973, p. 129) with at least 20 verticals per cross-section. Discharge values were highly predictable from stage height measurement using calculated regression equations with coefficients of determination (R^2), values greater than 0.98 for FEX and 0.99 for FCD.

Stream velocity was also recorded for the periphyton samplers (see Element 2) using the Gurley pygmy current meter about once each week.

Results and Discussion

A. Field Chemistry

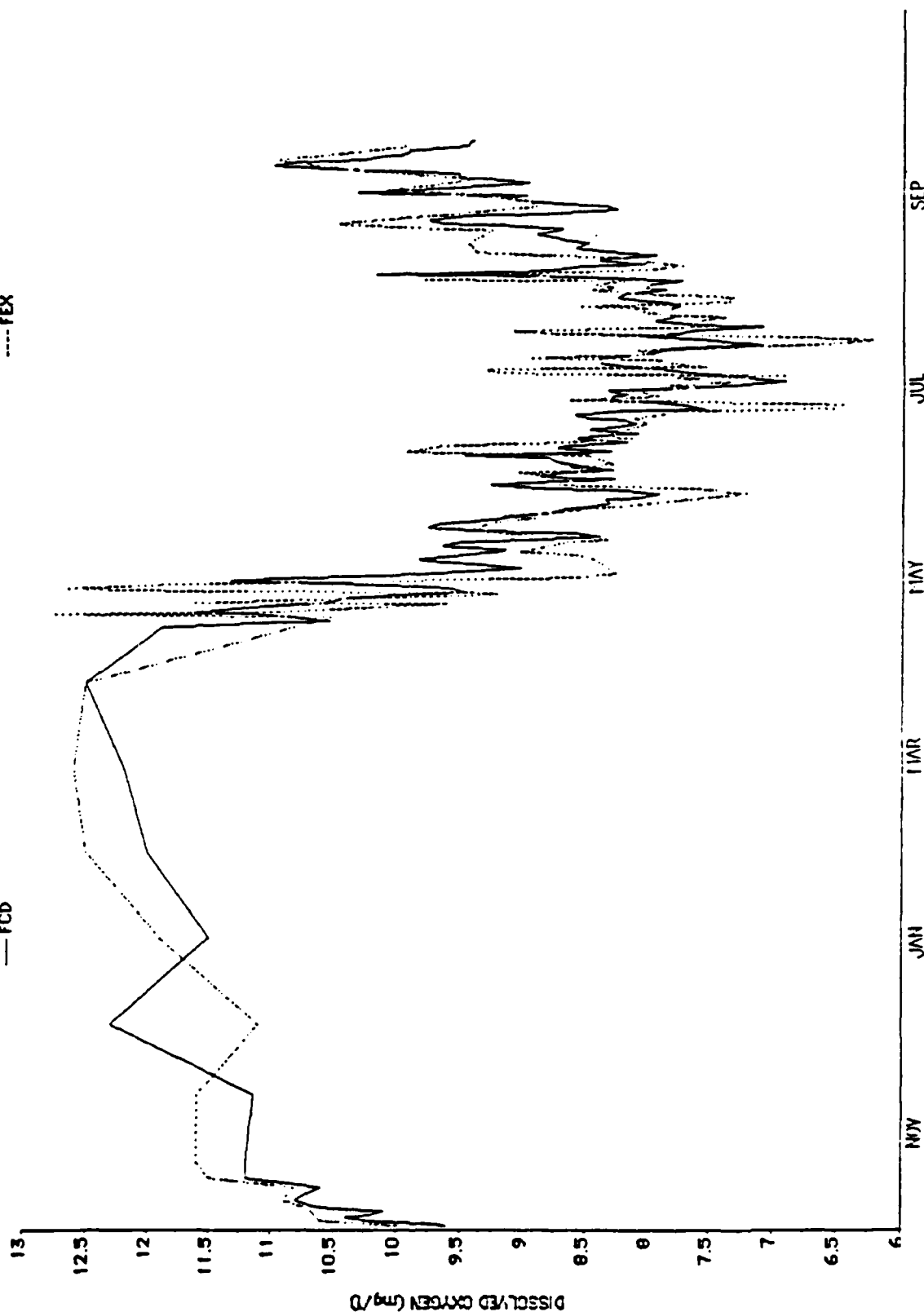
The 1986 dissolved oxygen data (Fig. 1.1) followed the trends established in previous years. These trends are that dissolved oxygen is typically 5-15% undersaturated in the river but varies from winter highs of more than 12 mg/l to summer lows of less than 8 mg/l. There are no

Fig. 1.1 DISSOLVED OXYGEN VALUES FOR THE FORD RIVER

10-1-85 10 9-23-86

---- FEX

— FCD



pronounced daily variations during most seasons (Fig. 1.2). Even those 24 hour periods with large diel variations such as the one in April can be explained primarily on the basis of temperature changes with little distinct diel pattern associated with production by plants. Paired t-tests demonstrated that there were no significant differences between the control (FCD) and impact (FEX) sites (Table 1.1). As expected, dissolved oxygen at FEX was correlated with dissolved oxygen at FCD (Correlation coefficient 0.7, $p < 0.01$). The data in Fig. 1.1 from April through September are automatically monitored data. Even with calibration of probes twice per week, drifting occurs so that these data do not agree as closely as the manually determined analyses reported in previous reports. Even so, no significant differences occur between sites (Table 1.1).

The pH data do not agree as closely as do the dissolved oxygen data (Fig. 1.3). In fact, there are significant differences between sites using the automatically acquired data of Fig. 1.3 (Table 1.1). If we use only manually determined pH data, these significant differences disappear. Thus, these differences appear to be related to the tendency of the pH probes to drift between calibration periods. Ultimately, this automatically acquired pH data may have to be examined in detail with portions of it discarded if drifting of the probes is excessive from one calibration period to the next. The manually determined data are more accurate and probably are all that are needed for correlation or regression with biological parameters. The automatically acquired data does allow routine monitoring of chemistry for detection of the "rare" pollution event if one should occur. The correlation coefficient (0.46) for pH at FEX and FCD is significant ($p < 0.01$) even with the automatically acquired data.

As in previous years, data for alkalinity, hardness, conductivity, turbidity, suspended solids and dissolved solids are very similar between FEX and FCD (Tables 1.2, 1.3, 1.4). None of these six parameters are significantly different between sites (Table 1.1). All values in these tables are summarized by 28 day periods that coincide with periphyton exposure times for diatom counts and chlorophyll a, and organic matter standing crop data.

B. Nutrient Chemistry

Nutrient chemistry samples are taken in the summer, frozen except for silicate which is refrigerated, and are analyzed during winter months. Thus, these analyses lag six months behind the field season and are reported on a calendar year basis. For 1985, soluble reactive and total phosphorus remained at the low levels previously reported for this nutrient poor river (Table 1.5). There were no significant differences between the control (FCD) and (FEX) sites (Table 1.6). Conversely nitrate-N, nitrite-N, and total inorganic-N were significantly different between the two sites (Tables 1.6, 1.7, 1.8), whereas ammonium-N and organic-N were not significantly different (Tables 1.6, 1.7, 1.8). Differences in nitrate and nitrite could be related to the proximity of FEX to a permanent residence on the river, perhaps related to septic tank effluent or run off from the horses associated with this residence. Indeed, the significantly higher chloride levels of FEX (Tables 1.6, 1.9)

Fig. 1.2 24H DISSOLVED OXYGEN CONTRASTS

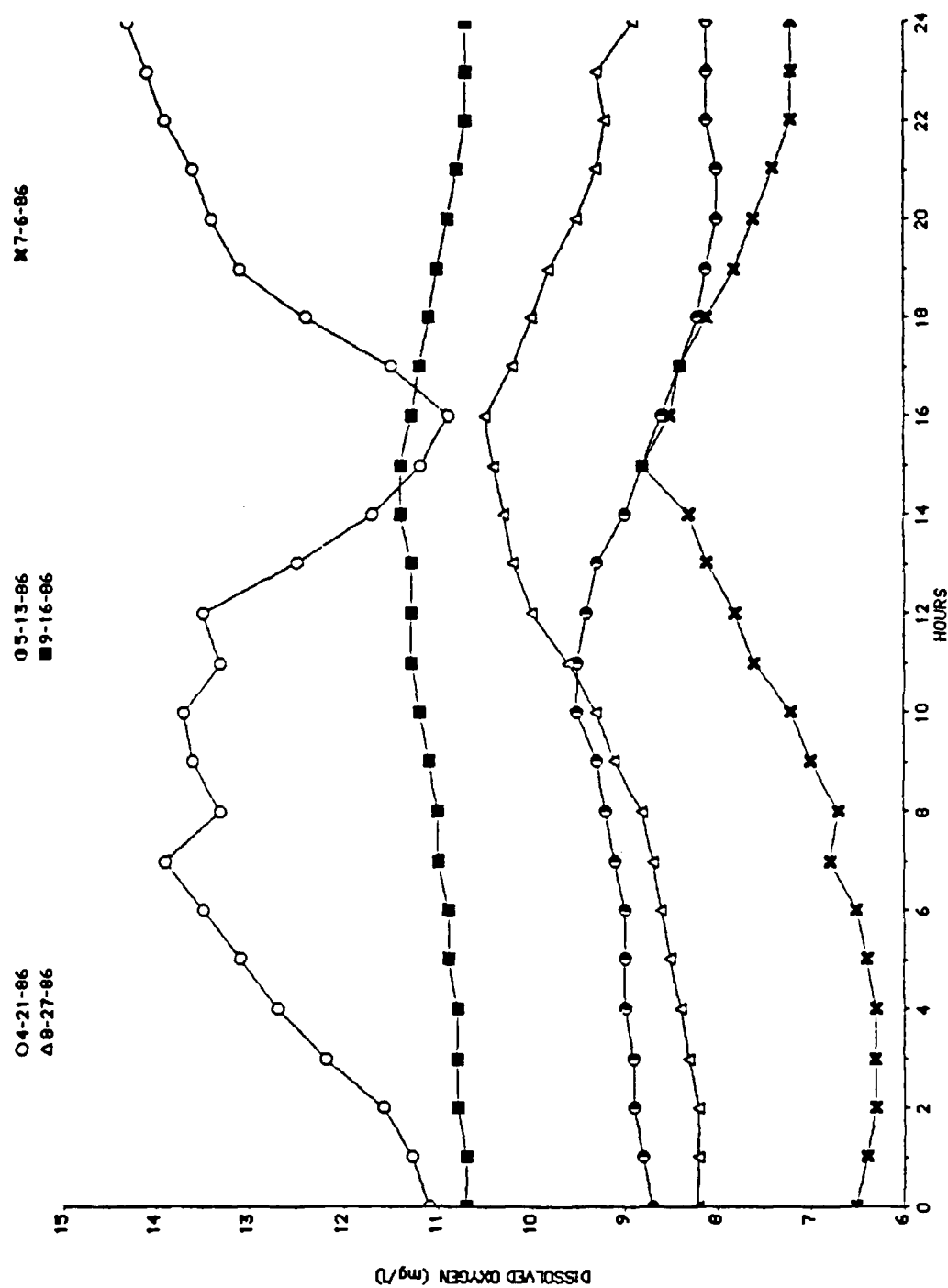


Table 1.1 Results of Paired t-tests for Mean^{9d} Field Chemistry Parameters Measured at the Impact (FEX) and Control (FCD) Sites.

Parameter	DF	Paired t Value	Probability
Hardness	12	0.63	NS
Alkalinity	12	1.74	NS
Suspended Solids	11	-0.99	NS
Dissolved Solids	11	-0.65	NS
Conductivity	10	-1.77	NS
Turbidity	11	0.35	NS
Dissolved oxygen	119	-1.38	NS
pH	153	-3.32	$C_p < 0.01$

Fig. 1.3 DAILY pH VALUES FOR THE FORD RIVER
4-17-06 TO 10-23-06

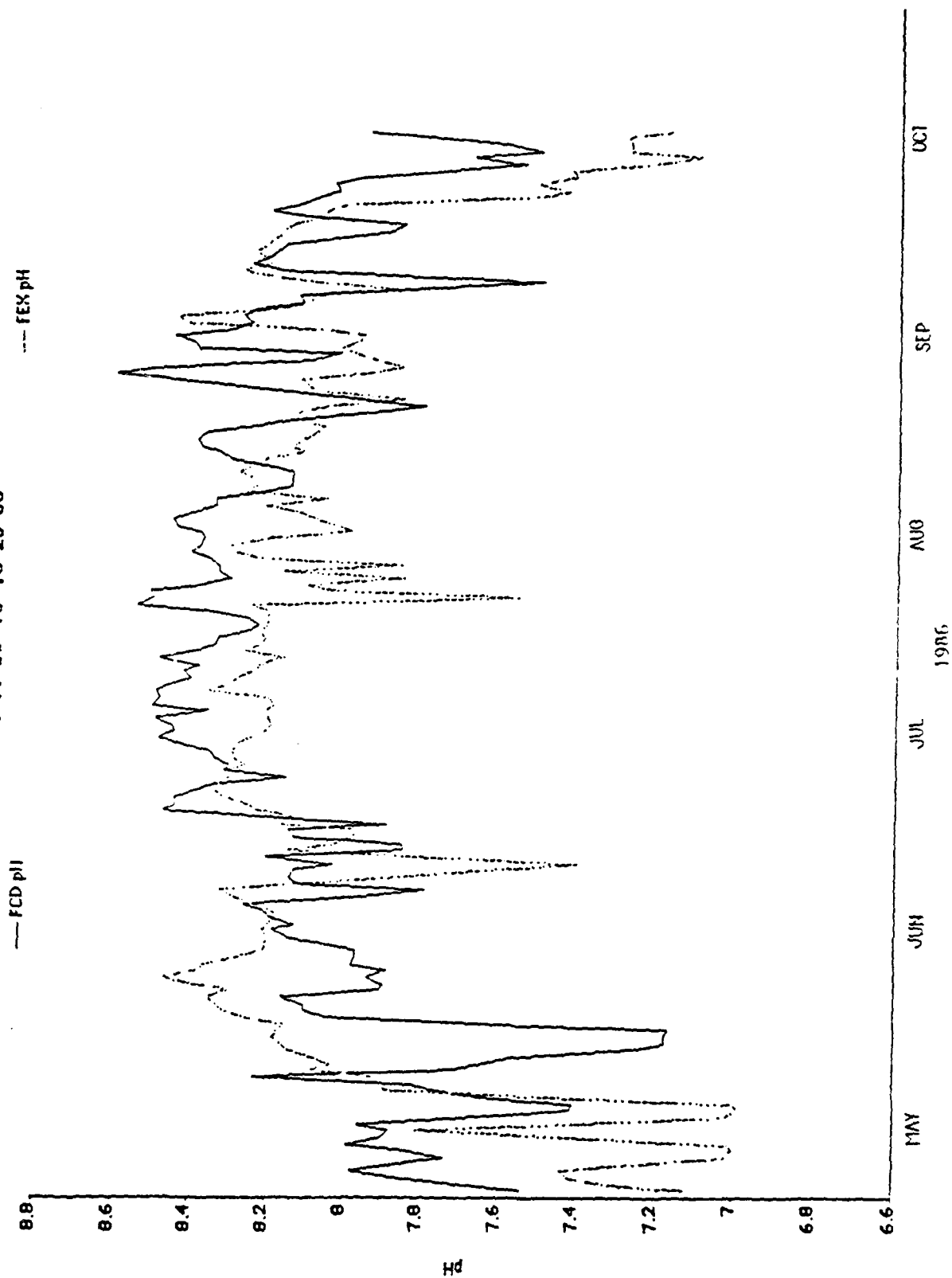


Table 1.2 Alkalinity (mg CaCO₃/L) and Hardness (mg CaCO₃/L) for the Ford River. Values are Means \pm SE, N in Parentheses.

DATES	Control Site (FCD)		Experimental Site (FEX)	
	Hardness	Alkalinity	Hardness	Alkalinity
9/24/85 - 10/22/85	119 \pm 16 (4)	101 \pm 10 (4)	114 \pm 7 (4)	95 \pm 9 (4)
10/15/85 - 11/13/85	124 (1)	98 (1)	140 (1)	105 (1)
11/8/85 - 12/6/85	117 (1)	97 (1)	128 (1)	93 (1)
12/6/85 - 1/3/86	158 (1)	122 (1)	146 (1)	119 (1)
1/3/86 - 1/31/86	150 (1)	126 (1)	149 (1)	121 (1)
1/31/86 - 2/28/86	163 (1)	139 (1)	160 (1)	134 (1)
2/28/86 - 3/28/86	129 (1)	112 (1)	117 (1)	105 (1)
3/28/86 - 4/25/86	103 (1)	81 (1)	100 (1)	77 (1)
4/21/86 - 5/19/86	135 \pm 12 (4)	122 \pm 12 (4)	131 \pm 12 (4)	119 \pm 12 (4)
5/19/86 - 6/16/86	173 \pm 3 (4)	161 \pm 3 (3)	170 \pm 3 (4)	158 \pm 3 (4)
6/16/86 - 7/14/86	177 \pm 2 (4)	168 \pm 2 (4)	178 \pm 3 (4)	170 \pm 2 (4)
7/17/86 - 8/14/86	183 \pm 1 (4)	169 \pm 2 (4)	183 \pm 2 (4)	174 \pm 3 (4)
8/14/86 - 9/11/86	179 \pm 1 (4)	169 \pm 1 (4)	176 \pm 2 (4)	165 \pm 2 (4)

Table 1.3 Conductivity (umhos/cm) and Turbidity (NTU'S) For the Ford River. Values are Means \pm S.E., N in Parentheses.

DATES	Control Site (FCD)		Experimental Site (FEX)	
	Conductivity	Turbidity	Conductivity	Turbidity
9/24/85 - 10/22/85	159 \pm 19 (4)	1.7 \pm 0.4 (9)	151 \pm 17 (4)	1.8 \pm 0.4 (9)
10/15/85 - 11/13/85	138 (1)	2.0 (1)	143 (1)	1.8 (1)
11/8/85 - 12/6/85	140 (1)	1.0 (1)	148 (1)	1.0 (1)
12/6/85 - 1/3/86	140 (1)	1.8 (1)	150 (1)	1.0 (1)
1/3/86 - 1/31/86	240 (1)	0.6 (1)		1.9 (1)
1/31/86 - 2/28/86		2.0 (1)	190 (1)	1.9 (1)
2/28/86 - 3/28/86	182 (1)		172 (1)	
3/28/86 - 4/25/86	108 (1)	1.5 (1)	108 (1)	1.8
4/21/86 - 5/19/86	183 \pm 12 (4)	1.4 \pm 0.2 (6)	182 \pm 14 (4)	1.3 \pm 0.2 (6)
5/19/86 - 6/16/86	230 \pm 10 (3)	0.9 \pm 0.1 (8)	241 \pm 13 (4)	0.8 \pm 0.1 (8)
6/16/86 - 7/14/86	259 \pm 3 (4)	1.3 \pm 0.2 (8)	283 \pm 8 (4)	1.0 \pm 0.1 (7)
7/17/86 - 8/14/86	272 \pm 4 (4)	1.1 \pm 0.3 (5)	278 \pm 7 (4)	1.2 \pm 0.2 (5)
8/14/86 - 9/11/86	234 \pm 8 (4)	1.7 \pm 0.8 (8)	241 \pm 9 (4)	1.1 \pm 0.2 (8)

Table 1.4 Suspended Solids and Dissolved Solids (mg/L).
Values are Means \pm SE, N in Parentheses.

DATES	Control Site (FCD)		Experimental Site (FEX)	
	Suspended Solids	Dissolved Solids	Suspended Solids	Dissolved Solids
9/25/85 - 10/22/85	4.6 \pm 2.1 (8)	177 \pm 7 (8)	3.4 \pm 1.4 (8)	180 \pm 5 (8)
10/15/85 - 11/13/85	1.3 (1)	158 (1)	0.9 (1)	147 (1)
11/8/85 - 12/6/85	3.1 (1)	161 (1)	2.1 (1)	150 (1)
12/6/85 - 1/3/86	1.9 (1)	188 (1)	2.0 (1)	209 (1)
1/3/86 - 1/31/86	2.1 (1)	144 (1)		
1/31/86 - 2/28/86	2.1 (1)	236 (1)	8.4 (1)	238 (1)
2/28/86 - 3/28/86			3.3 (1)	
3/28/86 - 4/25/86	2.9 (1)	124 (1)	2.3 (1)	131 (1)
4/21/86 - 5/19/86	1.6 \pm 0.4 (8)	167 \pm 14 (8)	1.5 \pm 0.3 (8)	156 \pm 13 (8)
5/19/86 - 6/16/86	0.7 \pm 0.1 (8)	196 \pm 10 (8)	0.5 \pm 0.1 (7)	184 \pm 7 (7)
6/16/86 - 7/14/86	0.5 \pm 0.2 (6)	186 \pm 14 (6)	0.6 \pm 0.2 (6)	202 \pm 10 (6)
7/17/86 - 8/14/86	1.0 \pm 0.1 (7)	228 \pm 7 (7)	2.1 \pm 1.2 (7)	221 \pm 6 (7)
8/14/86 - 9/11/86	0.4 \pm 0.1 (7)	236 \pm 19 (7)	0.3 \pm 0.1 (7)	233 \pm 14 (7)

Table 1.5 Soluble Reactive Phosphorus (ug P/L) and Total Phosphorus (mg P/L) for the Ford River for 1985. Values are Means \pm S.E., N in Parentheses.

DATES	Experimental Site (FEX)		Control Site (FCD)	
	Soluble Reactive-P	Total P	Soluble Reactive-P	Total P
1/9 - 2/6	1.4 (1)	11.7 (1)	2.9 (1)	23.0 (1)
2/6 - 3/7	8.8 (1)	18.4 (1)	5.4 (1)	13.0 (1)
3/7 - 4/4	4.8 (1)	56.3 (1)	2.0 (1)	6.6 (1)
4/4 - 5/2	2.9 \pm 0.2 (5)	38.3 \pm 22.9 (5)	3.6 \pm 0.2 (6)	35.2 \pm 9.0 (6)
5/2 - 6/3	2.4 \pm 0.4 (8)	22.0 \pm 3.3 (9)	4.3 \pm 0.5 (8)	22.0 \pm 3.6 (8)
6/3 - 7/1	4.8 \pm 1.6 (7)	4.7 \pm 0.6 (8)	2.7 \pm 0.8 (8)	24.7 \pm 5.7 (8)
7/1 - 7/29	3.3 \pm 1.0 (6)	13.5 \pm 3.8 (7)	3.2 \pm 0.2 (8)	26.8 \pm 9.2 (8)
7/29 - 8/26	3.3 \pm 0.9 (7)	17.9 \pm 1.8 (7)	2.6 \pm 0.2 (7)	18.5 \pm 1.2 (8)
8/26 - 9/24	5.2 \pm 0.6 (8)	28.0 \pm 4.3 (8)	6.5 \pm 0.7 (7)	27.7 \pm 3.4 (8)
9/24 - 10/22	4.8 \pm 0.8 (8)	33.0 \pm 5.4 (8)	4.8 \pm 0.6 (8)	28.1 \pm 2.6 (8)
10/16 - 11/13		21.5 (1)	3.3 (1)	29.1 (1)
11/8 - 12/7	2.2 (1)	16.9 (1)	2.6 (1)	32.0 (1)

Table 1.6 Results of Paired t-tests on Nutrient Chemistry Parameters for Control (FCD) and Impact (FEX) Sites for 1985.

Parameter	Paired t Value	df	Probability
Organic Nitrogen	-1.88	11	NS
Inorganic Nitrogen	-3.97	11	p<.01
Silicate-Si	0.41	11	NS
Chloride	3.13	11	p<.01
Ammonium-N	1.51	11	NS
Nitrate-N	-4.89	11	p<.001
Nitrite-N	3.22	11	p<.01
Total Kjeldahl-N	-1.73	11	NS
Soluble Reactive-P	0.56	10	NS
Total P	-0.07	11	NS

Table 1.7 Organic-N (ug N/L) and Inorganic-N (ug N/L)
For the Ford River for 1985. Values are Means
+ S.E., N in parentheses.

DATES	Experimental Site (FEX)		Control Site (FCD)	
	Organic Nitrogen	Inorganic Nitrogen	Organic Nitrogen	Inorganic Nitrogen
1/9 - 2/6	538 (1)	189 (1)	525 (1)	204 (1)
2/6 - 3/7	544 (1)	203 (1)	773 (1)	230 (1)
3/7 - 4/4	700 (1)	204 (1)	552 (1)	252 (1)
4/4 - 5/2	675 + 156 (6)	133 + 31 (6)	746 + 74 (6)	216 + 23 (6)
5/2 - 6/3	765 + 81 (9)	59 + 15 (9)	836 + 107 (8)	144 + 5 (8)
6/3 - 7/1	635 + 74 (8)	32 + 80 (8)	754 + 80 (8)	143 + 12 (7)
7/1 - 7/29	534 + 75 (7)	77 + 16 (7)	627 + 40 (8)	136 + 7 (8)
7/29 - 8/26	573 + 52 (7)	92 + 15 (7)	686 + 86 (8)	178 + 20 (8)
8/26 - 9/24	685 + 72 (8)	100 + 14 (8)	787 + 377 (8)	137 + 8 (8)
9/24 - 10/22	827 + 139 (8)	120 + 18 (8)	830 + 52 (8)	95 + 3 (8)
0/16 - 11/13	900 (1)	138 (1)	977 (1)	128 (1)
1/8 - 12/6	458 (1)	199 (1)	1283 (1)	322 (1)

Table 1.7 Organic-N (ug N/L) and Inorganic-N (ug N/L)
For the Ford River for 1985. Values are Means
+ S.E., N in parentheses.

DATES	Experimental Site (FEX)		Control Site (FCD)	
	Organic Nitrogen	Inorganic Nitrogen	Organic Nitrogen	Inorganic Nitrogen
1/9 - 2/6	538 (1)	189 (1)	525 (1)	204 (1)
2/6 - 3/7	544 (1)	203 (1)	773 (1)	230 (1)
3/7 - 4/4	700 (1)	204 (1)	552 (1)	252 (1)
4/4 - 5/2	675 + 156 (6)	133 + 31 (6)	746 + 74 (6)	216 + 23 (6)
5/2 - 6/3	765 + 81 (9)	59 + 15 (9)	836 + 107 (8)	144 + 5 (8)
6/3 - 7/1	635 + 74 (8)	32 + 80 (8)	754 + 80 (8)	143 + 12 (7)
7/1 - 7/29	534 + 75 (7)	77 + 16 (7)	627 + 40 (8)	136 + 7 (8)
7/29 - 8/26	573 + 52 (7)	92 + 15 (7)	686 + 86 (8)	178 + 20 (8)
8/26 - 9/24	685 + 72 (8)	100 + 14 (8)	787 + 377 (8)	137 + 8 (8)
9/24 - 10/22	827 + 139 (8)	120 + 18 (8)	830 + 52 (8)	95 + 3 (8)
0/16 - 11/13	900 (1)	138 (1)	977 (1)	128 (1)
1/8 - 12/6	458 (1)	199 (1)	1283 (1)	322 (1)

Table 1.8 Ammonium-N (ug N/L), Nitrate-N (ug N/L), Nitrite-N (ug N/L) and Total Kjeldahl-N (ug N/L) for the Ford River for 1985. Values are Means \pm S.E., N in parentheses.

DATES	EXPERIMENTAL SITE (FEX)			
	Ammonium-N	Nitrate-N	Nitrite-N	Total Kjeldahl-N
1/9 - 2/6	25.6 (1)	160 (1)	2.9 (1)	564 (1)
2/6 - 3/7	19.9 (1)	180 (1)	3.4 (1)	564 (1)
3/7 - 4/4	50.2 (1)	150 (1)	3.7 (1)	750 (1)
4/4 - 5/2	23.5 \pm 3.3 (6)	79 \pm 15 (6)	3.9 \pm 0.5 (6)	645 \pm 140 (6)
5/2 - 6/3	25.8 \pm 3.1 (8)	30 \pm 13 (9)	3.7 \pm 0.3 (9)	790 \pm 92 (8)
6/3 - 7/1	20.1 \pm 1.3 (8)	9 \pm 6 (8)	2.9 \pm 0.1 (8)	672 \pm 67 (9)
7/1 - 7/29	25.6 \pm 2.3 (7)	48 \pm 15 (7)	3.3 \pm 0.2 (7)	560 \pm 74 (7)
7/29 - 8/26	41.8 \pm 1.4 (7)	47 \pm 1 (8)	3.7 \pm 0.2 (8)	614 \pm 47 (7)
8/26 - 9/24	46.6 \pm 11.8 (8)	49 \pm 7 (8)	3.9 \pm 0.2 (8)	729 \pm 76 (8)
9/24 - 10/22	53.1 \pm 17.6 (8)	62 \pm 0 (8)	4.3 \pm 0.4 (8)	880 \pm 137 (8)
10/16 - 11/13	48.3 (1)	86 (1)	3.3 (1)	949 (1)
11/8 - 12/6	74.8 (1)	120 (1)	4.0 (1)	533 (1)
CONTROL SITE (PCD)				
1/9 - 2/6	23.0 (1)	178 (1)	2.8 (1)	548 (1)
2/6 - 3/7	18.0 (1)	208 (1)	3.5 (1)	791 (1)
3/7 - 4/4	23.0 (1)	226 (1)	2.5 (1)	575 (1)
4/4 - 5/2	46.5 \pm 28.9 (6)	165 \pm 13 (6)	4.6 \pm 1.7 (6)	792 \pm 68 (6)
5/2 - 6/3	12.8 \pm 2.1 (8)	122 \pm 6 (8)	2.6 \pm 0.1 (8)	849 \pm 107 (8)
6/3 - 7/1	21.6 \pm 2.5 (8)	119 \pm 9 (7)	2.6 \pm 0.3 (8)	775 \pm 81 (8)
7/1 - 7/29	23.9 \pm 5.1 (8)	110 \pm 5 (8)	2.4 \pm 0.2 (8)	651 \pm 40 (8)
7/29 - 8/26	64.6 \pm 16.3 (8)	108 \pm 6 (8)	2.7 \pm 0.1 (8)	751 \pm 72 (8)
8/26 - 9/24	36.1 \pm 7.2 (8)	98 \pm 4 (8)	3.3 \pm 0.2 (8)	824 \pm 36 (8)
9/24 - 10/22	35.6 \pm 3.7 (8)	60 \pm 3 (8)	3.9 \pm 0.2 (8)	865 \pm 53 (8)
10/16 - 11/13	13.4 \pm (1)	113 (1)	2.0 (1)	990 (1)
11/8 - 12/6	19.5 \pm (1)	125 (1)	2.0 (1)	1478 (1)

Table 1.9 Dissolved Silicate (mg Si/L) and Chloride (mg Cl/L) for the Ford River for 1985. Values are Means \pm S.E., N in parentheses.

DATES	Silica		Chloride	
	Experimental (FEX)	Control (FCD)	Experimental (FEX)	Control (FCD)
1/9 - 2/6	10.55 (1)	10.33 (1)	3.04 (1)	2.68 (1)
2/6 - 3/7	11.51 (1)	10.87 (1)	0.68 (1)	2.32 (1)
3/7 - 4/4	10.60 (1)	10.20 (1)	3.13 (1)	3.96 (1)
4/4 - 5/2	5.63 \pm 0.1 (2)	7.36 \pm 1.5 (2)	2.50 \pm 0.4 (5)	2.06 \pm 0.2 (6)
5/2 - 6/3	5.75 \pm 0.1 (8)	6.01 \pm 0.1 (8)	3.38 \pm 0.6 (9)	2.12 \pm 0.1 (8)
6/3 - 7/1	7.20 \pm 0.7 (8)	6.62 \pm 0.1 (7)	4.27 \pm 0.9 (8)	2.12 \pm 0.5 (8)
7/1 - 7/29	6.56 \pm 0.3 (7)	6.02 \pm 0.8 (7)	4.50 \pm 0.3 (7)	2.24 \pm 0.1 (8)
7/29 - 8/26	9.40 \pm 0.2 (8)	7.53 \pm 1.0 (8)	6.50 \pm 1.2 (8)	3.74 \pm 0.4 (8)
8/26 - 9/24	8.60 \pm 0.7 (7)	8.52 \pm 0.5 (8)	5.43 \pm 0.8 (8)	3.35 \pm 0.3 (8)
9/24 - 10/22	7.59 \pm 0.3 (8)	7.10 \pm 0.2 (8)	4.68 \pm 0.5 (8)	2.70 \pm 0.3 (8)
10/16 - 11/13	8.60 (1)	10.07 (1)	4.46 (1)	2.40 (1)
11/8 - 12/6	9.27 (1)	9.27 (1)	4.42 (1)	2.50 (1)

support this explanation. Even so differences between the two sites are not very large for nitrate, nitrite, and chloride (Table 1.8, 1.9), and all other nutrient parameters are not significant between the two sites (Tables 1.6-1.9). The lack of significant correlations between any of the nitrogen constituents and any of the periphyton community measurements as reported in last year's report coupled with the low between site differences for N suggest that the measured differences have little or no impact on the biotic parameters that are being measured.

We instituted a quality control program in 1984 for laboratory analyses on stored samples. The most important component of that program is addition of a field spike to a paired sample where both the regular sample and the spike are subjected to identical handling, storage, and analytical procedures. The results of these analyses (Table 1.10) indicate excellent recoveries of ± 10 percent for chloride, silicate, total phosphorus, and nitrate-N in both years. Every constituent except soluble reactive P was within 10% of expected values in 1985. Even Soluble Reactive P was within 20 percent of expected recovery. This reduced rate of recovery for P could be related to sorption on filters during the filtering process in the field, sorption on the walls of the storage containers during storage, or to the relatively poor levels of replicability expected for a constituent which, in field samples, is always near the limits of accurate detection (5 ug/l) for the autoanalyzer procedure (Table 1.5). In general, standard errors for recoveries are also low (Table 1.10) with the exception of Ammonium-N and Soluble Reactive P. Ammonium is very volatile and subject to low levels of contamination just from ambient air in the laboratory. Even so, the fact that all recoveries except soluble P were within 10 percent of expected in 1985 suggests that our analytical procedures are providing us with high quality data.

C. Physical and Meteorological Parameters

The primary physical parameters monitored include air and water temperature, above and below water photosynthetically active radiation (PAR), and stream discharge. Most of these parameters are measured by automatic monitoring equipment from mid-April through mid-October. Solar radiation (PAR) is highly variable as one would expect (Fig. 1.4). As reported in previous reports, it does not correlate very well with even the periphyton data, since a 28 day exposure for periphyton colonization leads to questions about the appropriate mean PAR to use in the analyses. In future years, we expect to attempt correlations based on total cumulative PAR per exposure period.

Stream discharge is highly correlated between sites (Fig. 1.5, $R^2 = 0.99$), but there is a tendency, as would be expected, for the upstream station (FEX) to have slightly lower discharge than does the downstream station (FCD). Any differences in current velocity between sites is compensated for by careful placement of samples for periphyton and insect studies in positions with similar current velocities (e.g. see element 2). Since fish studies emphasize migration, slight differences in current velocity should pose no problem.

Air and water temperature are monitored, and these data are available as needed. Water temperature during the ice-free season is highly variable but rarely exceeds 20°C (Fig. 1.6). Under the ice in

Table 1.10 Percent Recovery of Known Amounts of Nutrients Added to Field Samples at Time of Collection. Values are Means \pm S.E. N in Parentheses.

Chemical Constituent	Percent Recovery	
	1984	1985
Soluble Reactive P	—	81.5 \pm 9.7 (20)
Total P	104.1 \pm 8.2 (11)	94.7 \pm 6.1 (18)
Nitrate-N	98.5 \pm 2.8 (26)	91.7 \pm 3.3 (27)
Nitrite-N	87.7 \pm 1.7 (25)	92.5 \pm 2.0 (29)
Ammonium-N	87.3 \pm 4.9 (22)	101.6 \pm 22.7 (13)
Total Kjeldahl N	—	109.1 \pm 4.6 (18)
Chloride	102.4 \pm 0.9 (28)	103.0 \pm 3.3 (24)
Silicate-Si	94.3 \pm 0.9 (26)	98.2 \pm 1.5 (27)

Fig. 1.4 SOLAR RADIATION
FEX---1986

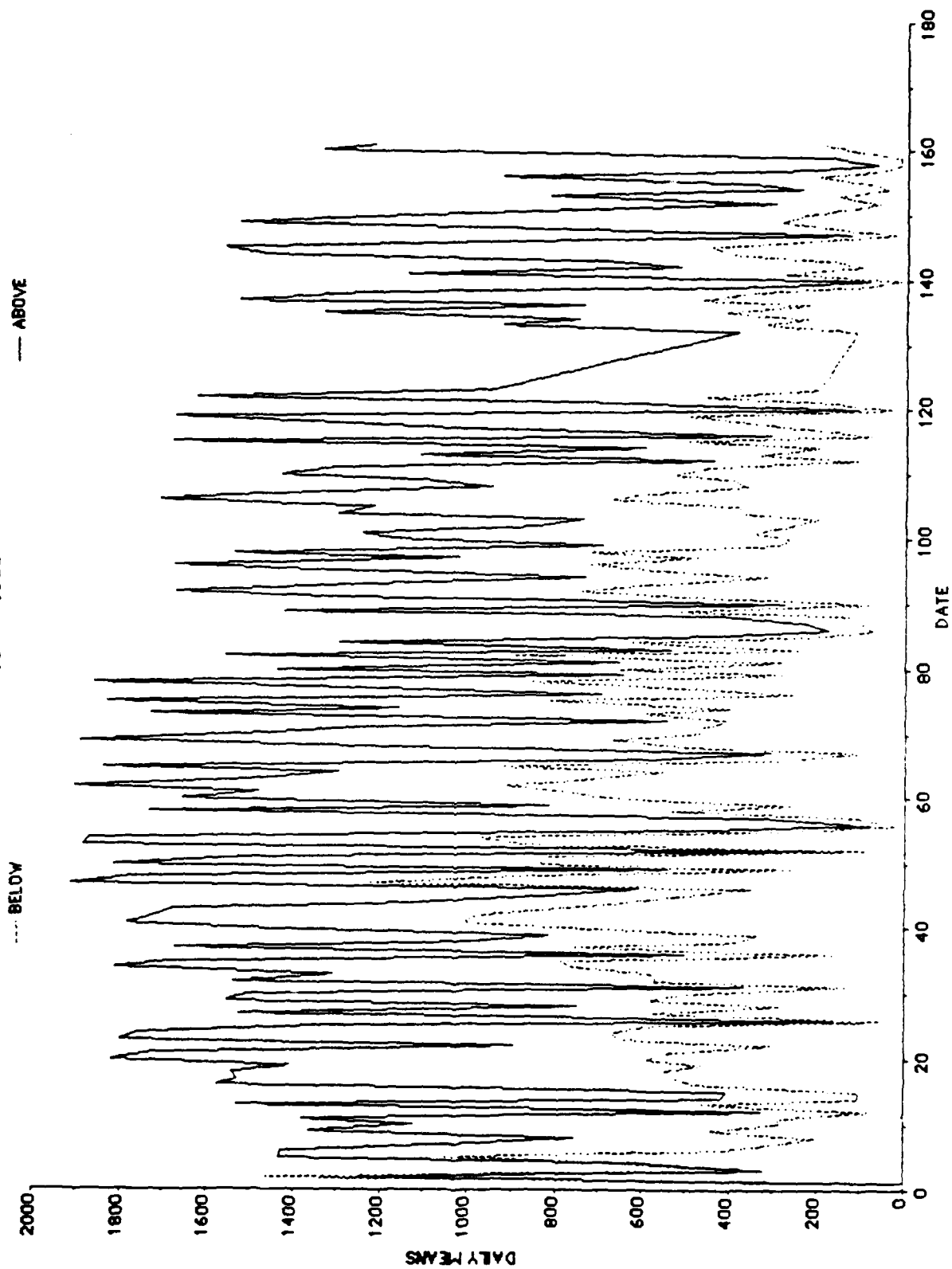


Fig. 1.5

Discharge Comparisons
4-21-86 TO 9-11-86

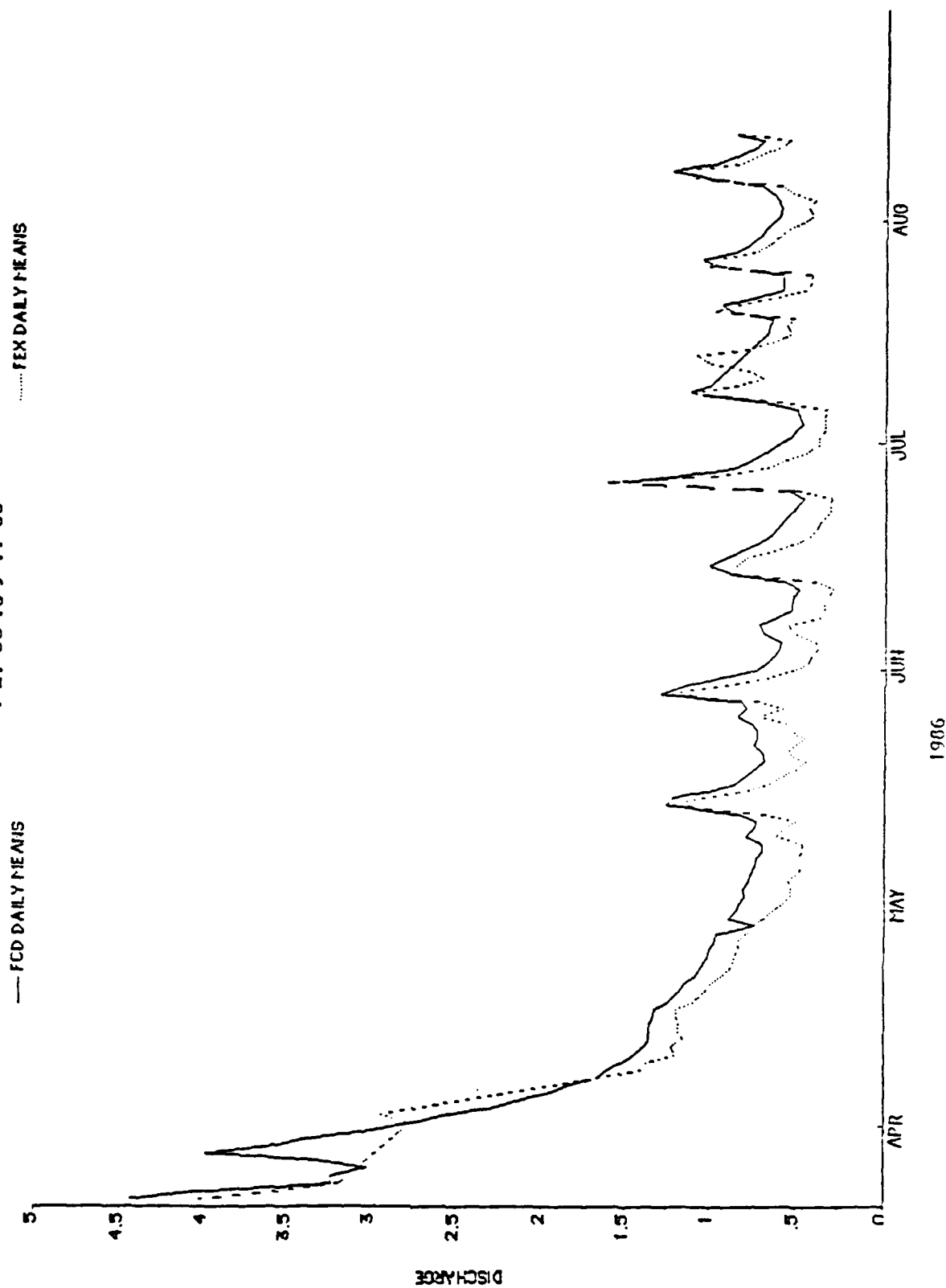
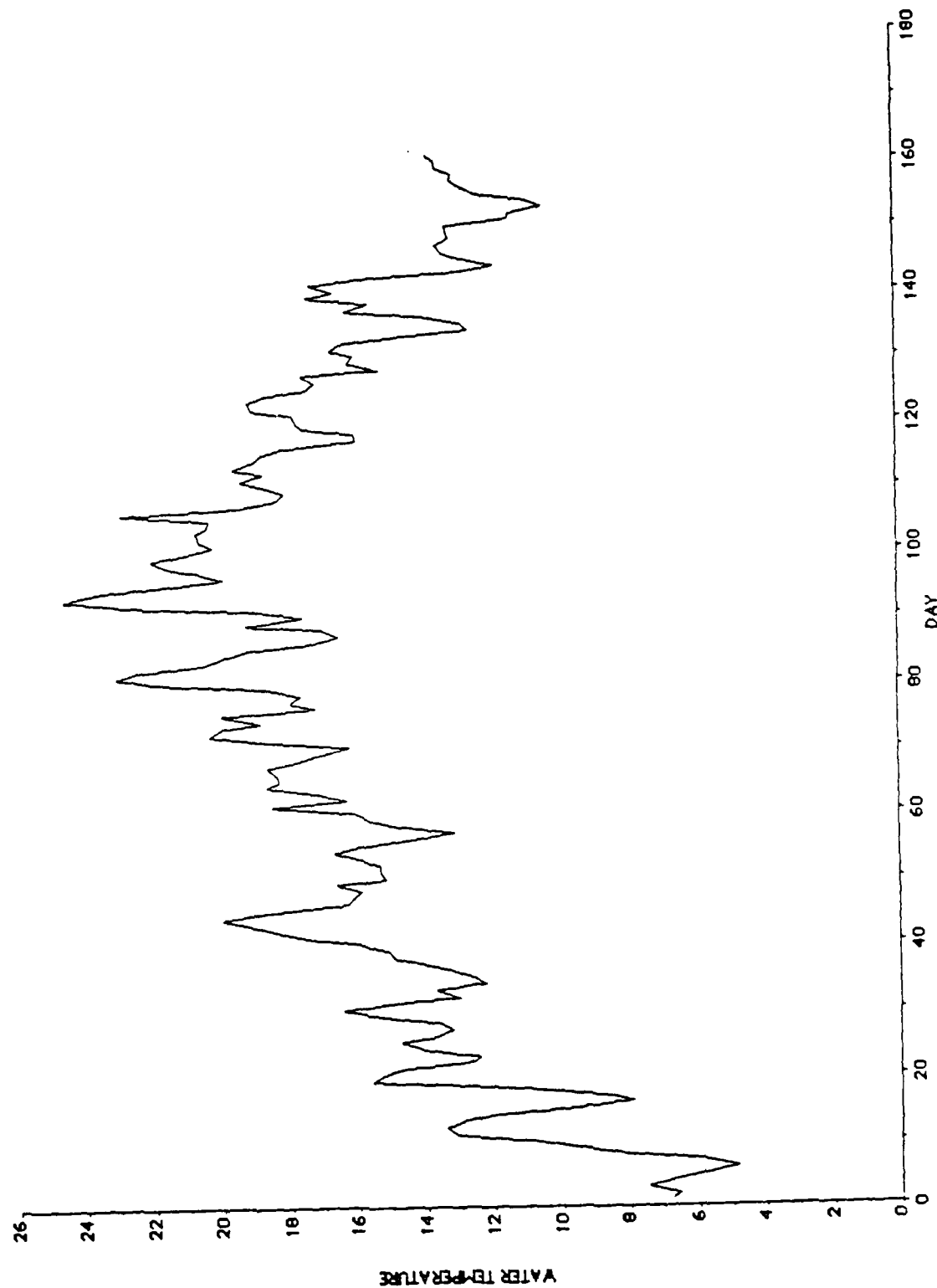


Fig. 1.6 AVERAGE DAILY FORD RIVER WATER TEMPERATURE
4/17/86 - 9/11/86



winter, temperature is almost always 0°C when measured during monthly sampling trips.

As reported in previous reports, precipitation data are available from Iron Mountain and Crystal Falls weather stations. To supplement these data, we maintain a manual rain gauge at each site during the ice-free season. These data are summarized in Fig. 1.7.

D. Summary

Ambient monitoring data are available to fulfill the objectives for this element. These data show that FCD and FEX are very comparable sites with only minor differences from site to site. These data also demonstrate the excellent water quality of the Ford River. These data have been used in the biotic monitoring program with correlations between periphyton, insects, and fish and appropriate ambient monitoring data having been examined. Some of these correlations will be presented in the following elements. The correlations between various physical and chemical parameters reported in this element will be useful in interpreting the results of correlations between ambient monitoring and biotic parameters. The background data established by this procedure will also allow us to detect any shifts in water quality that might occur from unexpected pollution events or land use changes.

References

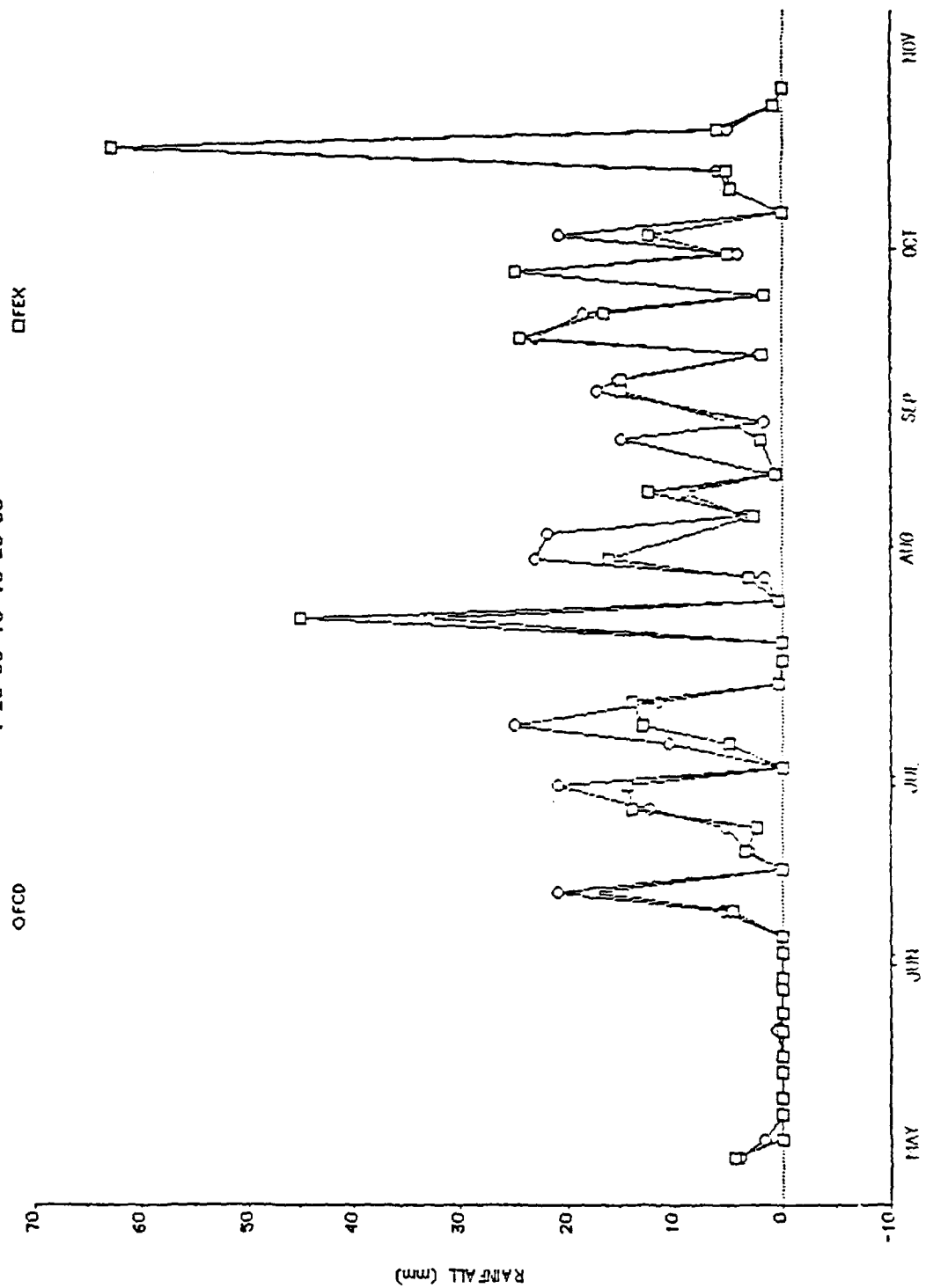
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Fig 1.7 RAIN DATA COLLECTED AT BOTH FORD RIVER SITES
4-28-86 TO 10-23-86



VII.A. PERIPHYTON STUDIES

Element 2 - Monitoring of Species Composition, Numbers, Diversity, Organic Matter Accrual Rates and Standing Crop, Cell Volume, and Chlorophyll a / Phaeophytin a Accrual Rates and Standing Crop for Periphyton

Changes from workplan - None.

Objectives

The objectives of the periphytic algal studies are:

- (1) to quantify any changes in species diversity, species composition, species evenness, species richness and cell density that occur as a result of ELF electromagnetic fields,
- (2) to quantify any changes in primary productivity that might occur as a result of ELF electromagnetic fields,
- (3) to monitor any changes in chlorophyll a and organic matter accrual rates and standing crops as a result of ELF electromagnetic fields, and
- (4) to determine algal cell volumes and chlorophyll a to phaeophytin a ratios, thereby providing indices of physiological stress in periphytic algal cells that might occur as a result of ELF electromagnetic fields.

Rationale

Structural Community Indices: Community composition of the attached algae has often been used by researchers to indicate subtle or dramatic changes in water quality. The effects of toxicants, nutrients, or other pollutants has often been linked to changes in abundances of particular diatom species and often to the presence or absence of sensitive species. The use of a species diversity index coupled with measurements of species evenness and richness allows between site comparisons of attached algal communities which will include the subtle shifts in species composition that may potentially occur as a result of ELF radiation. The dominant diatom community which develops on exposed glass slides often consists of 50-70 species on a single slide out of an estimated species pool for the Ford River of over 300 total species. The potential changes in species abundance, species diversity and species evenness of this community afford sensitive and statistically measurable parameters against which to measure seasonal variation, site variation, yearly variation and potential ELF effects.

In 1986, we became aware of a new procedure developed by Stewart-Oaten et al. (1986) for detecting before and after effects. This Before and After, Control and Impact design

(BACI) appears to have considerable potential for both individual species and community level comparisons. Thus, we present computations in this report for a few species of diatoms to illustrate the technique and how we expect to use it for before and after individual diatom species comparisons. It appears to have potential to detect more subtle changes than we have been able to document heretofore. We also expect to use this procedure for community parameters that "track" each other at the two sites but have high coefficients of variation. For example, organic matter accrual rates expressed as ash free dry weight and chlorophyll a accrual rates on glass slides appear to be amenable to this type of analysis.

In addition to studying the species composition of the attached algae, we are examining the relatively simple parameter of overall cell density. This directly determined density measure represents the numerical end product of species succession and abundance of dominance shifts by individual species in the attached algae community, and also includes the effects of physical environmental factors. The use of cell density, which is affected by both biological and physical factors, may thus reveal changes due to ELF effects. This single parameter, while perhaps less sensitive to small disturbances, is a very important correlate with other estimates of production such as chlorophyll a, or organic matter accrual. This labor intensive direct counting procedure is thus the yardstick against which other production estimates are often compared and should help separate potential ELF induced effects from other biological or physical influences.

Functional Community Indices: Measurement of the amounts of chlorophyll a, the primary photosynthetic pigment used by all algae, affords both quantitative and qualitative comparisons between sites. The quantity of chlorophyll a present can be directly measured through intensity of fluorescence and can be correlated with cell density and cell volume to indicate the relative or qualitative physiological state of the algal community. Subtle effects of ELF electromagnetic fields on the photosynthetic pigment may result in cellular "leaking" or a general physiological weakening of individual cells. This weakening may decrease both the total quantity of chlorophyll a present as well as reduce the amount of oxygen generated through photosynthesis. Including the ratios of the main chlorophyll a degradation product, phaeophytin a, can also indicate the degree of physiological stress in the algal community. Site comparisons of the relative amounts of oxygen produced by the attached algae will then compare the final results of photosynthesis.

This multiple approach of methodologies couples direct determinations of quantities of pigments present, with indirect physiological measurements of pigment condition, with further direct measurements of oxygen levels produced by that pigment. These parameters thus allow statistical comparisons of production between sites throughout the year. Utilizing

several different approaches allows us to continue analyses throughout the winter time when we rely more on measuring chlorophyll a and organic matter accrual to provide estimates of production, since the more detailed production studies are not feasible.

Our rationale has thus been to provide multiple data sets taken independently, incorporating several methodologies in order to detect and separate any "real" differences as a result of ELF electromagnetic radiation.

Materials and Methods

Plexiglass slide racks were designed to hold 8 or 10 standard 7.6 x 2.5 cm glass slides in a vertical placement oriented facing the current in the river. These slide racks were fastened to bricks and placed in riffle habitats at the control (FCD) and experimental sites (FEX). Slides were removed after 14 days for chlorophyll a, phaeophytin a, and organic matter biomass accrual rates and after 28 days for chlorophyll a, phaeophytin a and organic matter standing crop determination and for counts of algal cells for determination of density, species diversity, evenness and for determination of cell volumes. Ten slides were sampled for analysis of chlorophyll a and organic matter accumulation at each sampling interval and 5 slides were sampled for cell counts and cell volume determination after 28 days.

For species composition, cell counts, and cell volume determinations, 5 slides were removed on each sampling period from each habitat. Three slides were air dried and the other two were placed in a mixture of 6 parts water, 3 parts 95% ethanol and 1 part formalin. The air dried slides were later scraped in the lab with razor blades to remove the diatoms for further specimen cleaning and slide preparation. The other two slides were used to determine species composition of non-diatom algae.

Slides were prepared for specimen identification by cleaning the diatoms removed from the exposed glass slides in concentrated hydrogen peroxide (30%) followed by further oxidation of the cellular contents with the addition of small amounts of potassium dichromate (Van der Weff 1955). The cleaned diatoms were then rinsed with distilled water and settled in graduated cylinders. The final volume of concentrate containing the cleaned diatom frustules was then measured and 1 ml subsamples pipetted onto 22 mm² coverslips, until an adequate counting density was achieved. The coverslips were air dried and permanently mounted on glass slides using Hyrax medium.

Counting was done at 1250 X magnification on a Zeiss microscope equipped with phase contrast illumination and an oil immersion 100 X NEOFLUAR phase objective with numerical aperture of 1.30. Transects were taken moving across the

coverslip until between 250-450 frustules were counted. Estimates of diatom densities were made from quantitative samples via the equation:

$$\text{cells m}^{-2} =$$

$$\frac{(\text{Valves counted}) (\text{mm}^{-2} \text{ of coverslip}) (\text{ml of concentrate})}{2(\text{mm}^{-2} \text{ counted}) (\text{ml of subsample}) (\text{m}^{-2} \text{ of slide surface})}.$$

Diatom species composition was recorded for the 250-450 frustules for determination of species richness, diversity using the Shannon-Wiener formula (Southwood 1978), evenness, and dominance. Cell volume measurements were taken by measuring lengths, widths and depths and recording shapes of dominant diatoms for later calculation of cell volume based on formulae for combinations of various geometric shapes.

During 1986, ten slides were taken for chlorophyll a and phaeophytin a determinations for each exposure period from each site. Analyses for both chlorophyll a and phaeophytin a followed the fluorometric determination described in Method 1003C in Standard Methods (APHA 1980). All samples were analyzed within a month of collection. Initial analyses suggested that there were no differences in chlorophyll a and phaeophytin a between samples where the cells had been scraped from the slide and ground to facilitate cell rupture and samples with the grinding step eliminated. Subsequently, slides were collected, frozen for at least 24 hours to promote cell rupture, and extracted in 90% buffered acetone. Chlorophyll a and phaeophytin a were then determined following procedures outlined in Standard Methods.

During 1986, ten slides were also taken at each site for organic matter biomass determination. Analyses were conducted following procedure 1003D for productivity estimates in Standard Methods (APHA 1980). While using the gain in ash-free dry weight per unit area as a measure of net production (APHA 1980), we realize that determining rates of primary production from a temporal series of biomass measurements results in minimal estimates of net production. The losses that may occur from excretion of organic compounds, respiration, mortality, decomposition, emigration, or grazing are not included in determining this production estimate (Wetzel 1975). The accrual of biomass is a combination of processes involving dynamics of both colonization and production. Results from our study of the colonization component on biomass accrual should increase the accuracy of these production estimates. Rather than list results as production, we will refer to them as organic matter accrual rates.

All 1986 slide samples were frozen and analyzed within 30 days of collection time. Early 1983 samples were more variable

than later samples since invertebrates were not all removed before ash-free dry weight determination. This problem was rectified in June, 1983, and all data subsequent to that time are of organic matter on slides after removal by hand of visible invertebrates such as black flies from the slides.

Statistical comparisons between sites for the 1985-86 report emphasized paired t-tests to contrast the 28 day samples of chlorophyll a, organic matter, and cell densities between the experimental and control sites. In addition, paired t-test comparisons were made of the calculated indices of species diversity and species evenness between sites. The paired t-test was suggested by the statistical reviewer for last years annual report as being one of the more appropriate tests. The completion of the diatom volume computer program also allowed us to calculate the total biovolume of all diatom cells on the glass slides for each site. This additional parameter was also statistically tested between sites for 1985-86, as it was for 1984-85, and will eventually be expanded to calculate earlier biovolumes from previous years. Investigated in detail this year was the average individual diatom cell volume. These two parameters, individual cell volume and biovolume, provided additional information from correlations with other biological data, such as chlorophyll a or biomass levels at both sites.

In addition to the paired t-tests performed on data collected between sites, we analyzed the data using single and multiple regressions, as well correlations. We also performed transformations on the original data sets and performed subsequent correlations to determine whether linear relationships were the best solutions. Reciprocal transformations, power, and log transformations indicated that for most of the variables the linear equations were adequate in accounting for most of the shared variance. This year, for the first time, we also performed some exploratory factor analyses utilizing principal components.

The use of the factor analysis was helpful in selecting variables to use in our multiple regressions of biological versus chemical and ambient parameters. We obtained higher explained variance between biological and chemical or ambient parameters this year (see regression results) than in previous years.

Since we presented three-way analysis of variance for most data last year, we elected not to repeat these analyses this year. Nevertheless, we do consider this technique to be an excellent way to test our results and do expect to use multiple ANOVA analyses in the final treatment of data upon project completion.

While we increased the complexity and sophistication of our statistical methods during 1985 over those of the 1983-84

report, the inherent variability between samples was still high. For example, cell density, chlorophyll a and biomass accruals had coefficients of variation (C.V.'s) between 10-110% for 1983-84. In an effort to reduce this variability, increased sample numbers were taken during 1984-85. The number of samples required for a precise, single time point comparison was still prohibitively large (more than twenty-five samples or slides of each parameter). This number of samples was too costly and too labor intensive to be practical. However, chlorophyll a and organic matter samples were increased to 10 per sample date. This increased effort in 1984-85 reduced the range of the C.V.'s for chlorophyll a to between 4-88% , with an average of 32% and for organic matter to between 11-93%, with an average of 40%. With the exception of one highly variable sample in January, 1986, the C.V.'s for chlorophyll a for 1985-86 were in the range of 10-90% with a mean C.V. of 42%. However, organic matter C.V.'s averaged 64% in 1985-86. Cell density estimates were based on 3 slides per sample date and had a C.V. range between 3-115%, with an average of 38% in 1985. The average for 1986 was 39%. All three important biological parameters, thus showed average C.V.'s too high to detect subtle differences due to ELF effects. Derived measurements of species diversity or species evenness showed much smaller C.V. ranges of between 1-27%, with averages of 10% and 6.6% for species diversity and evenness. The individual C.V.'s observed for our monthly samples of biological parameters often fell below the 20% level commonly used in benthic studies (Cummins 1975), and statistical comparisons made between sites at such times therefore provided a sample size sufficient to be 95% certain of detecting a 40% difference in means between the two sites at the .05 significance level (Sokal and Rohlf 1969). Coefficients of variation tend to be lower during low flow periods in summer when flow conditions are low and more predictable. Thus, statistical comparisons using paired t-tests may have to emphasize such peak events for detection of subtle differences. We also expect to compare overall trends using multiple ANOVA analyses and, perhaps, time trend analysis. We have also examined the use of the BACI technique (Stewart-Oaten et al. 1986) using individual species data. These results will be presented below and are promising for certain species and may be useful for chlorophyll a and organic matter accrual rate comparisons.

The abilities of both water chemistry parameters and environmental conditions to predict levels of biological variables were investigated through the use of extensive multiple regression analyses. All data obtained after final site selection in June 1983 through June 1985 were analyzed and reported in the last annual report. In addition, all ambient data from the in situ probes and recorders were summarized and included in similar multiple regression comparisons for June 1983-June 1985. The use of multiple regressions together with correlation matrices often indicate potential interrelationships between physical, chemical or biological parameters.

These regressions were calculated for the 1986 data for this report. Eventually, regressions of pre-ELF exposure data for each site can be compared with post-ELF exposure data.

Results and Discussion

A. Colonization Patterns

In previous annual reports (AE-020, AE-031 and AE-045 for 1982/1983, 1983/1984 and 1984/85), we summarized data on colonization patterns for periphyton for the Ford River. These data demonstrated that a 14 day sampling period was reasonable during the active growing season (mid June to mid September) for estimates of daily chlorophyll a productivity and rates of organic matter accumulation for the Ford River. This 14 day period coincided with the period of rapid increases in chlorophyll a, phaeophytin a, and accrual of organic matter on slides. Thus, it minimized losses due to sloughing, etc. that increase as the periphyton community "matures" or approaches its maximum sustainable density on the slides (Burton and King 1983). This period of maximum daily increase in organic matter and chlorophyll a is often used as a measure of net production (APHA 1980; Burton and King 1983). Since the period of maximum daily increase was prolonged during cold weather, we used the 28 day period for estimates of daily productivity or accrual rate during the winter months and the 14 day period from April through October.

After 14-21 days during periods with temperatures above 15°C, data from the previous annual reports (AE-031) showed that the community composition changed slowly through time and qualitatively approximated the mature community on natural substrates in the stream. Thus, standing crop estimates of chlorophyll a, phaeophytin a, organic matter, and all community composition parameters (density, species diversity, species evenness, and species dominance) are based on a 28 day sampling program throughout the year. All 1985/1986 data were based on this 14 and/or 28 day sampling regime. As reported in the 1982-1983 annual report (AE-020), differences between pool and riffle habitats were either slight or insignificant. Thus, all samples are presently collected from riffle areas only. Data on colonization dynamics were written up for publication and appeared in Hydrobiologia in 1986. This paper is included as Appendix A.

B. Annual Patterns for Chlorophyll a

Final site selection was completed in 1983. Data from June, 1983 to August, 1986 for 28 d chlorophyll a standing crop showed that annual patterns differed markedly through time (Fig. 2.1). Even so, annual patterns did emerge. Each year, there was a peak in standing crop that occurred in July or August. The magnitude of the peak varied from values as large

as 12-14 $\text{mg}\cdot\text{m}^{-2}$ in 1983 to lows of 4-7 $\text{mg}\cdot\text{m}^{-2}$ in 1984. The 1986 peak was intermediate and similar to the 1985 peak with values of $7.7 \pm 0.7 \text{ mg}\cdot\text{m}^{-2}$ at FCD and $9.8 \pm 1.2 \text{ mg}\cdot\text{m}^{-2}$ for FEX on August 14 (Fig. 2.2). Another consistent pattern has been that chlorophyll a standing crop has been less than $1.0 \text{ mg}\cdot\text{m}^{-2}$ under the ice in winter (Fig. 2.1). The high annual variability component has been the period of late March through June with secondary peaks in chlorophyll a standing crop occurring in 1984 and 1986 but not in 1985. This secondary peak seems to be associated with dry spring seasons with low flows and relatively warm temperatures following snow melt runoff events. Certainly, May, 1986 was one of the driest and warmest Mays on record.

Daily chlorophyll a accrual rates followed the same pattern as did standing crop with July-August peaks and winter lows (Fig. 2.3). The August peak was $122 \pm 8 \text{ ug}\cdot\text{m}^{-2} \text{ day}^{-1}$ for FCD and $192 \pm 14 \text{ ug}\cdot\text{m}^{-2} \text{ day}^{-1}$ for FEX (Fig. 2.4). Both standing crop and daily accrual rates were very similar between FEX and FCD, and there were no significant differences between the sites in 1986 (Table 2.1). These two sites also were characterized by no significant differences in chlorophyll a for 1984-85 but were different in 1983-84. In 1984, we carefully placed slides with respect to current velocity (Fig. 2.4A), shading, and depth, and this careful placement has resulted in comparable results for the last two full years of data collection. We may have to delete the first years data from subsequent analyses because of the significant between site differences during that year. In the last annual report we reported that results from a 3 way ANOVA for the first two years data indicated a strong interaction with sample date and year being significant ($p < 0.01$) and with sample data providing the single most significant source of variation ($p < 0.001$). We have also calculated coefficients of variation for each month. These C.V.'s are in the 20-30% range when standing crop is near its peak. Thus, comparison of peak standing crop differences and daily accrual rates will allow us to detect more subtle differences than will use of data for the entire year. Even so, we consider annual patterns of chlorophyll a to be important parameters in that they allow us to select time periods of low potential variability (peaks in standing crop) for "point" analysis.

C. Annual Patterns of Organic Matter Accumulation

Organic matter measured as accumulation of ash free dry weight (AFDW) on glass slides followed the same trends as did chlorophyll a (Fig. 2.5, 2.6). There were peaks in July-August of each year of $1200 \text{ mg}\cdot\text{m}^{-2}$ or more with winter lows of about $250 \text{ mg}\cdot\text{m}^{-2}$ (Fig. 2.5). If anything, organic matter standing crop was more variable than chlorophyll a. Generally, FEX and FCD were comparable, but there were major differences for certain dates (e.g., September 11, 1986) (Fig. 2.6). Even so, no significant differences existed between FEX and FCD for

Table 2.1 Results of Paired t-test of Species Diversity (H'), Species Evenness, Diatom Cell Density, Cell Volume, Biovolume, Chlorophyll a, and Biomass between Control (FCD) and Experimental (FEX) Sites.

Test Parameter	df	Paired t-value	Probability (two tailed)	Sig.
SPECIES DIVERSITY (H')	12	-.417	.684	NS
SPECIES EVENNESS (J)	12	.752	.466	NS
CELL DENSITY	12	.076	.941	NS
CELL VOLUME	12	-.685	.506	NS
BIOVOLUME ($\ln x$)	12	2.437	.031	$p < .01$
BIOVOLUME	12	-.225	.826	NS
CHLOROPHYLL a STANDING CROP	12	1.068	.307	NS
CHLOROPHYLL a DAILY ACCRUAL	12	-.475	.643	NS
ORGANIC MATTER DAILY ACCRUAL	12	-1.106	.290	NS
ORGANIC MATTER STANDING CROP	12	-1.352	.201	NS

CHLOROPHYLL-a STANDING CROP FOR THE FORD RIVER **6-27-83 to 9-11-86**

Fig. 2.1

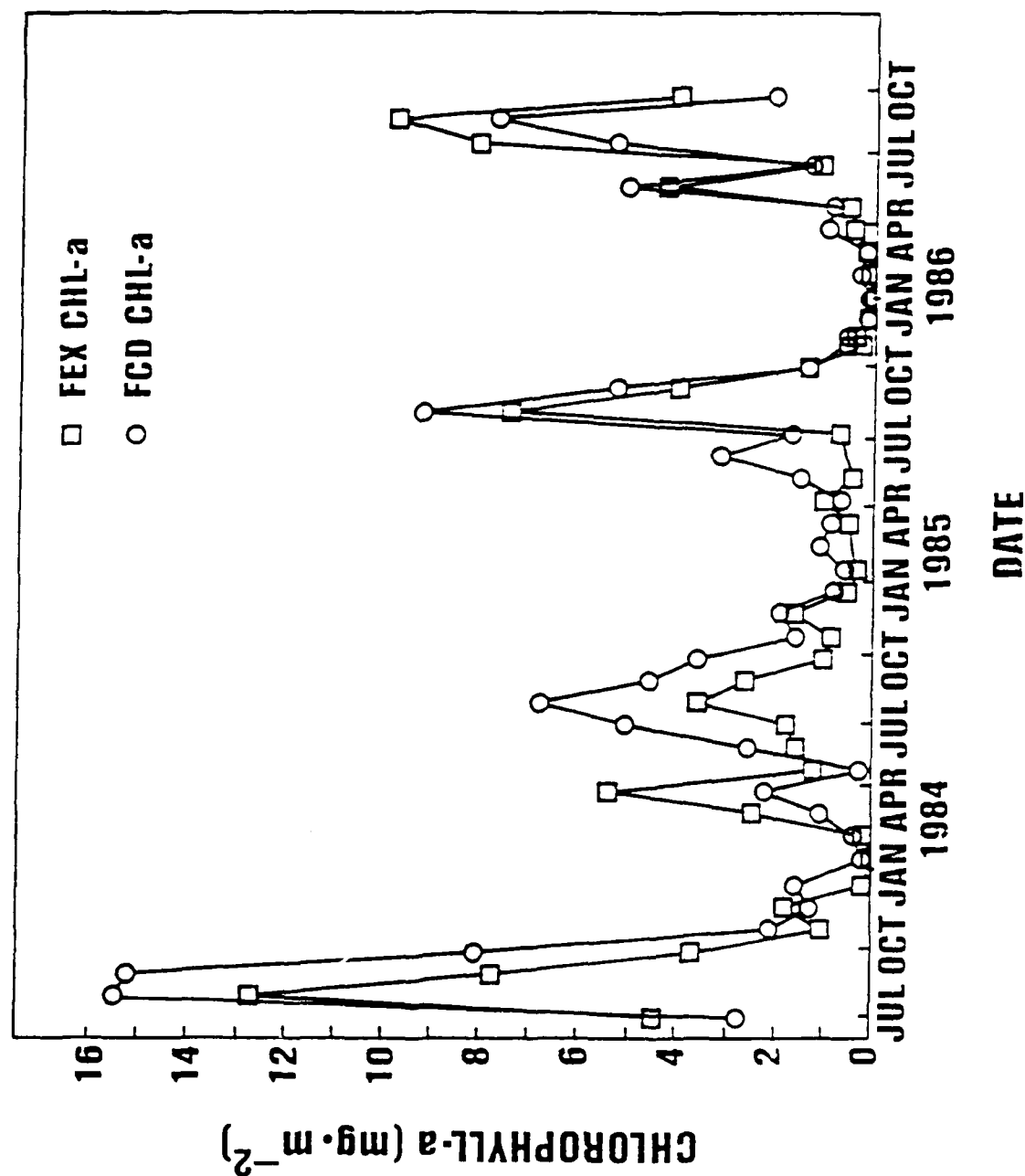


Fig. 2.2 **CHLOROPHYLL-a STANDING CROP FOR THE FORD RIVER**
10-23-85 to 9-11-86

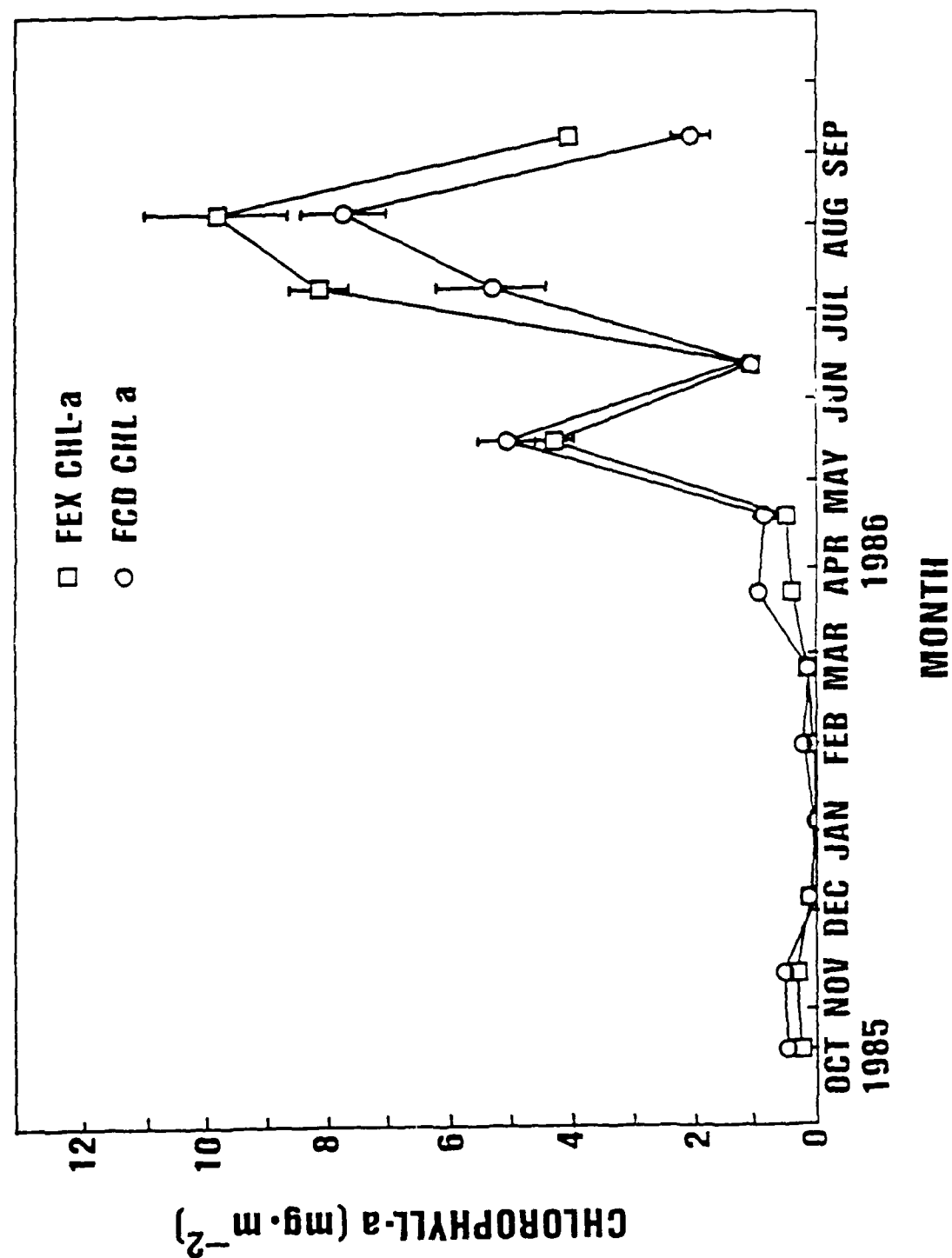


Fig. 2.3 ACCRUAL RATES OF CHLOROPHYLL-*a* FOR THE FORD RIVER
6-13-83 TO 9-26-86

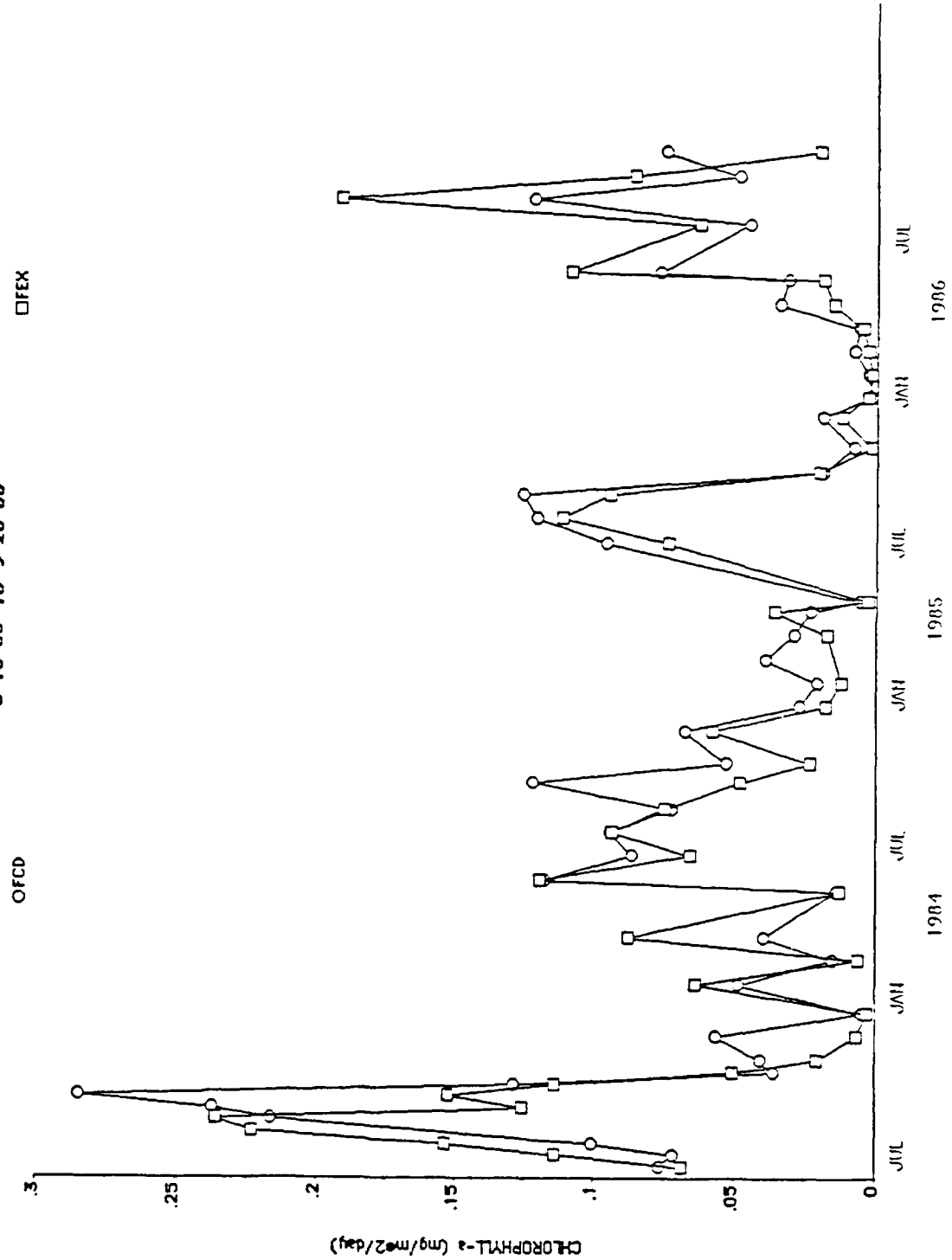


Fig. 2.4 ACCRUAL RATES OF CHLOROPHYLL-*a* FOR THE FORD RIVER
10-9-85 TO 9-25-86

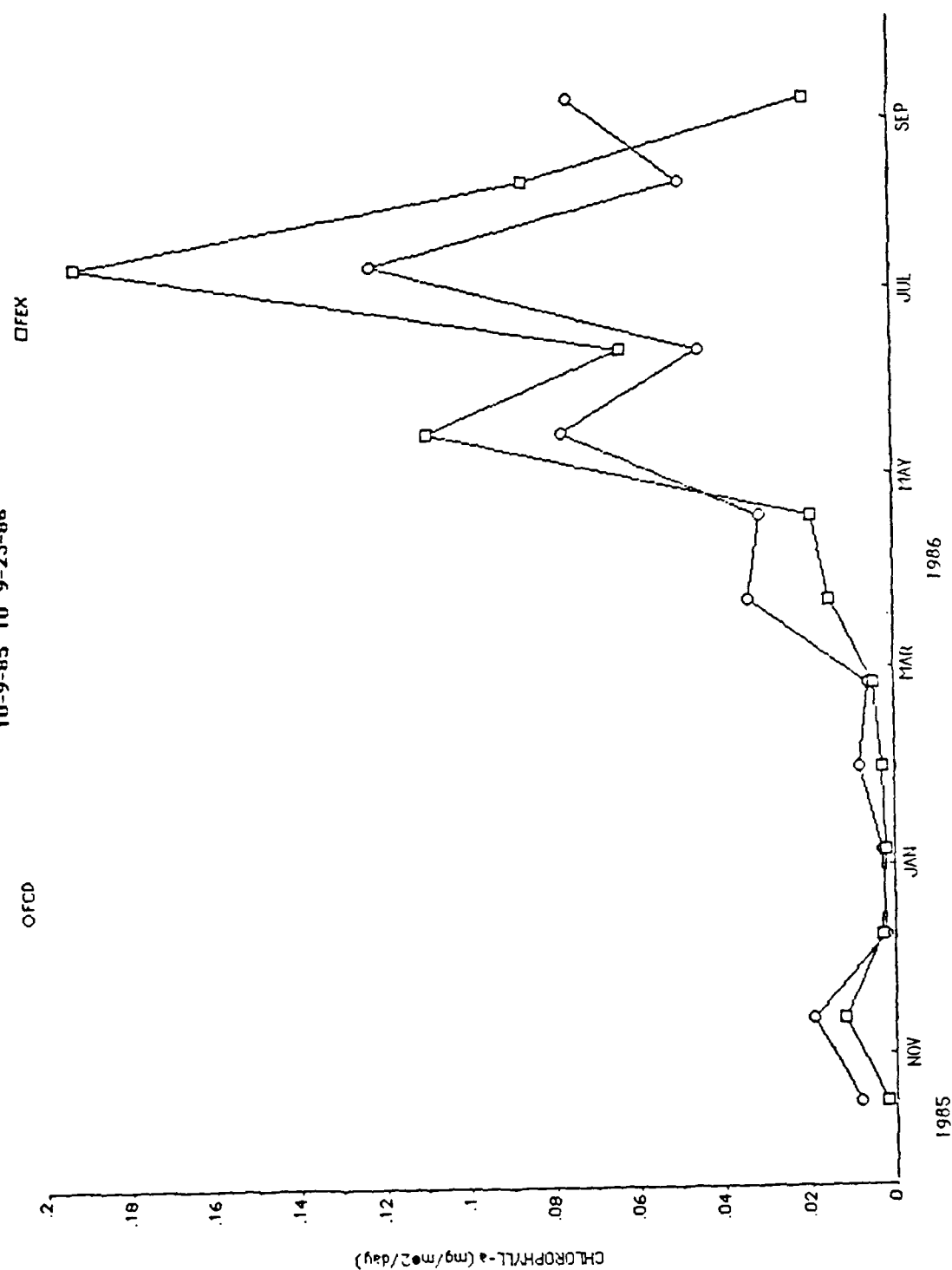


Fig. 2.4A PERIPHYTON SAMPLER WATER VELOCITY
5/05/86-10/20/86

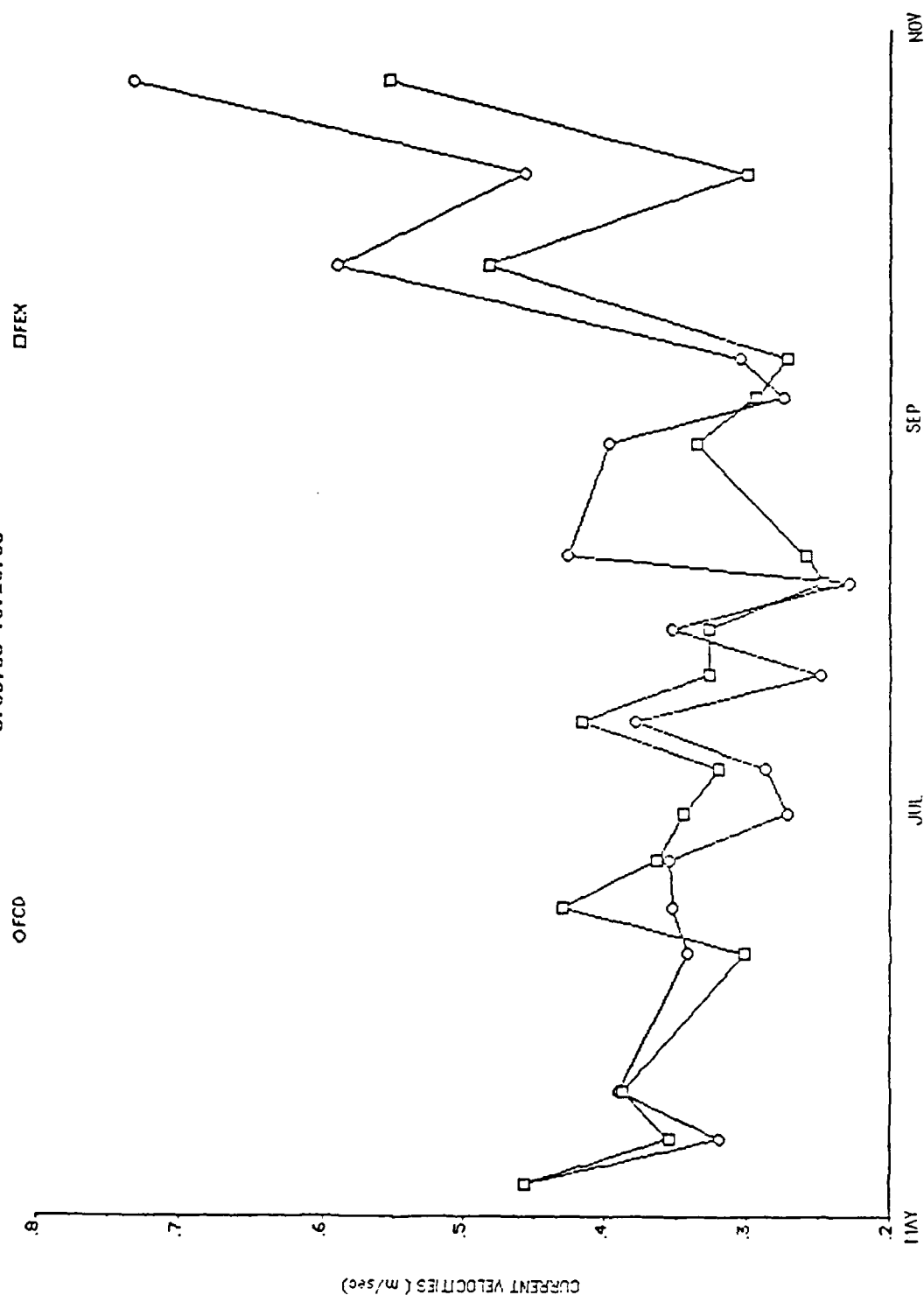


Fig. 2.5 **ORGANIC MATTER STANDING CROP FOR THE FORD RIVER**
6-27-83 to 9-11-86

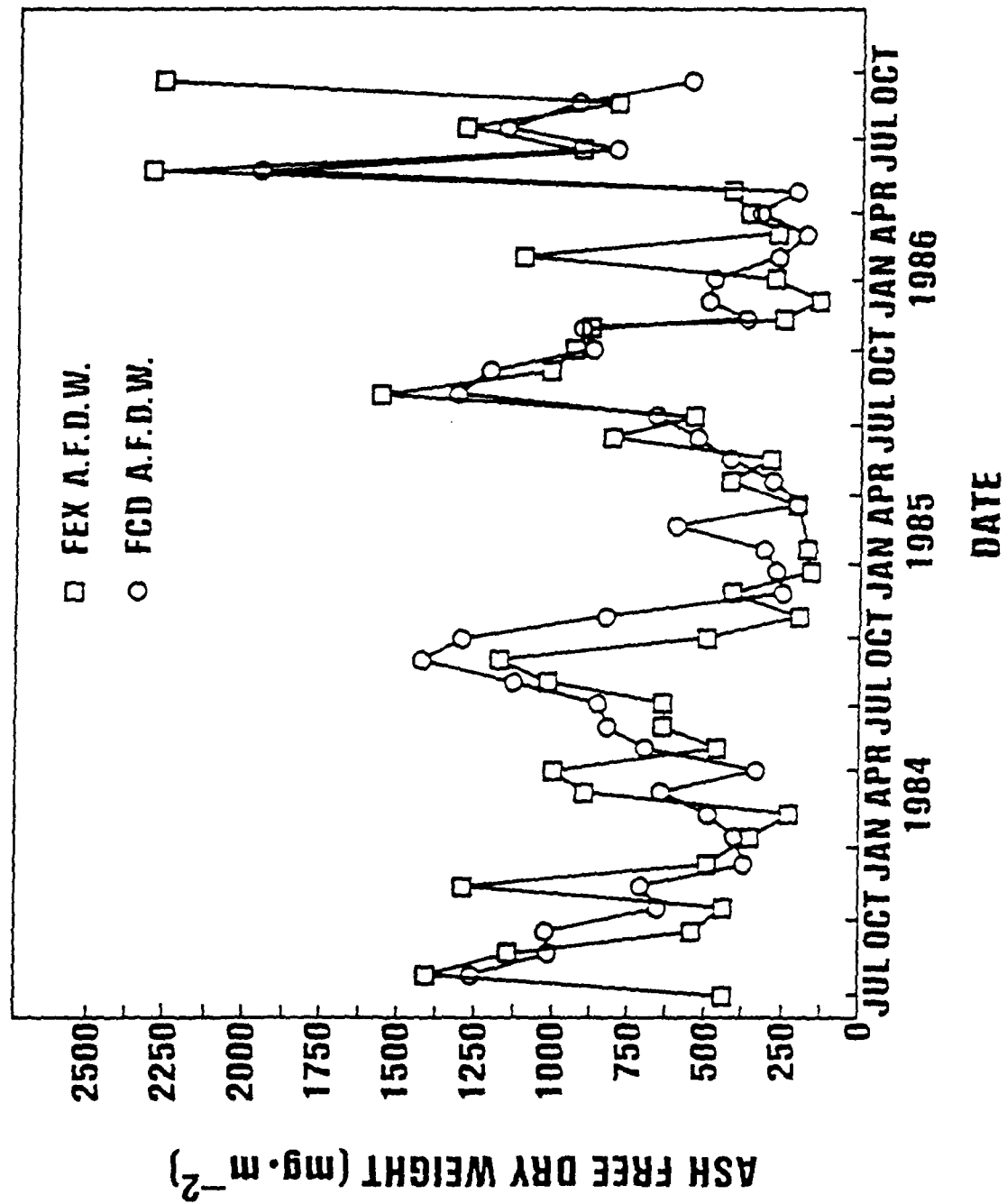
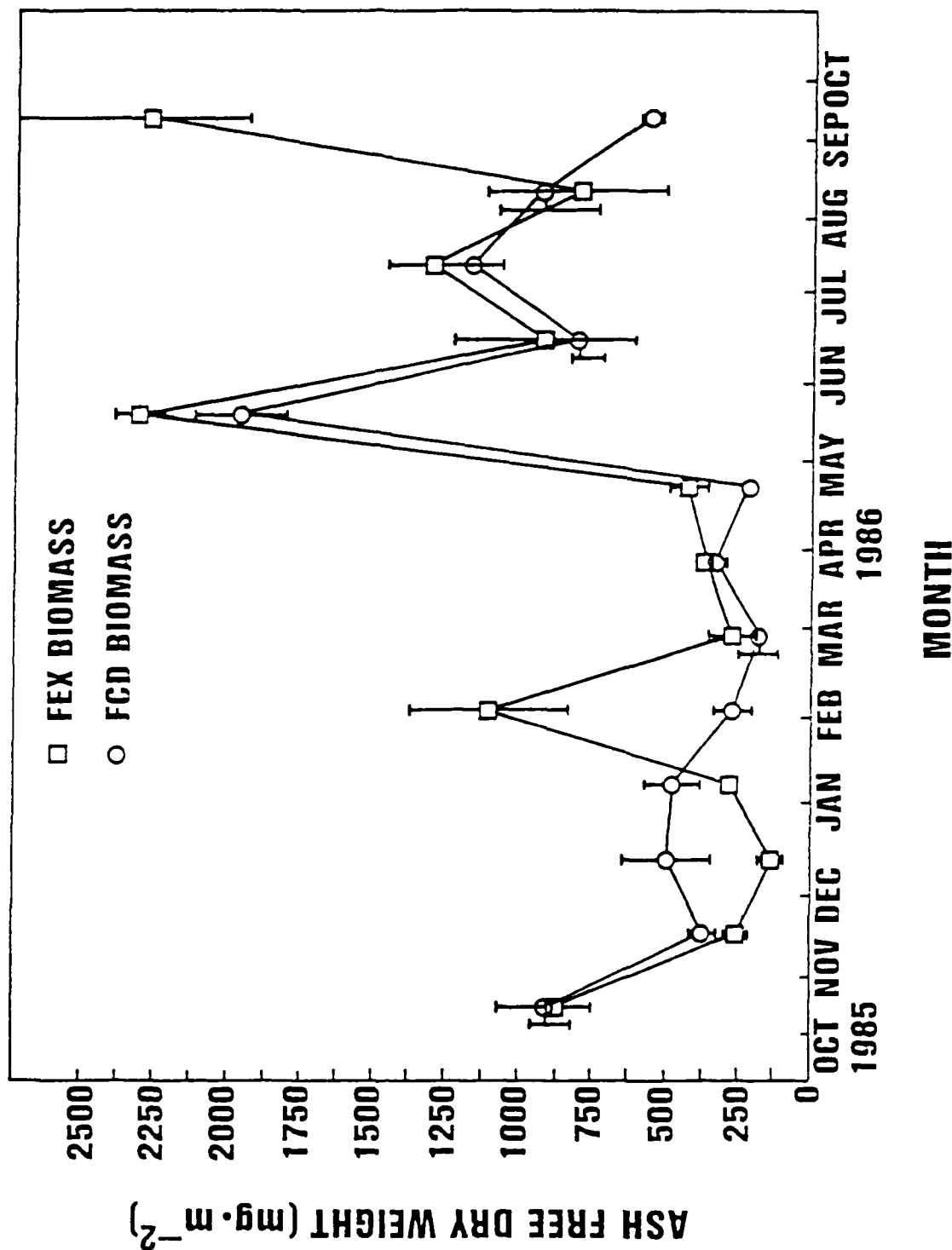


Fig. 2.6 **ORGANIC MATTER STANDING CROP FOR THE FORD RIVER**
10-23-85 to 9-11-86



the organic matter standing crops (Table 2.1). High coefficients of variation suggest that these data will not allow us to detect subtle differences that might occur as a result of ELF. However, the general agreement between sites coupled with the lack of significant differences between sites for any years examined (see past reports) make this parameter potentially useful for BACI analysis (see below), for the time series analysis which we expect to do next year, or for multiple ANOVA analysis. The 3 way ANOVA reported in the last report showed no between site differences.

Daily accrual rates of organic matter (AFDW) also showed high variability but general agreement between sites for both long term data (Fig. 2.7) and for the 1985-86 year just completed (Fig. 2.8). Despite the high variability there were no significant differences between sites in 1986 (Table 2.1) or any previous year.

D. Annual Pattern of the Ratio of Chlorophyll a to Phaeophytin a

The ratio of chlorophyll a to phaeophytin a was measured every 28 days as part of the analysis to index the phytoplankton biomass and to determine the physiological health of the algal community (APHA 1980). This ratio was found to be highly variable ranging from 1.4 to 76 for the experimental site and 0.6 to 38 for the control for previous years, and this trend continued in 1985-86 (Table 2.2). Because of the high degree of variability in this ratio, it is not very useful for comparing ELF effects between the experimental and control sites.

E. Annual Pattern of Diatom Cell Density

Diatom cell density showed wintertime low levels (Table 2.3) during December, January, February, and March. A wintertime low of 11×10^6 to 25×10^6 cells·m⁻² occurred at FEX on January 1st and 31st respectively (Fig. 2.9) while FCD wintertime lows ranged from 26×10^6 to 46×10^6 cells·m⁻² on December 6, 1985 and January 3, 1986. The tendency for FCD to have greater cell densities than FEX for most of 1983, 1984 and 1985 continued through 1986 (Fig. 2.10). Analysis of the data by paired t-tests, however, showed no significant differences between sites for 1986 (Table 2.10) as had been the case for previous years. This agreed with results from a 3-way ANOVA of cell density estimates between the sites for 1983 through 1985, as reported in the last annual report. The robustness of the paired t-test, as well as the high correlation coefficient ($r=.89$, $p<.01$) obtained between FCD and FEX cell densities (Table 2.4) indicated a lack of significant between site differences in cell density.

The two sites continue to show sustained high densities throughout each summer with winter lows (Fig. 2.10). The lack

Fig. 2.7 ACCRUAL RATES OF ORGANIC BIOMASS FOR THE FORD RIVER
6-13-03 TO 9-26-06

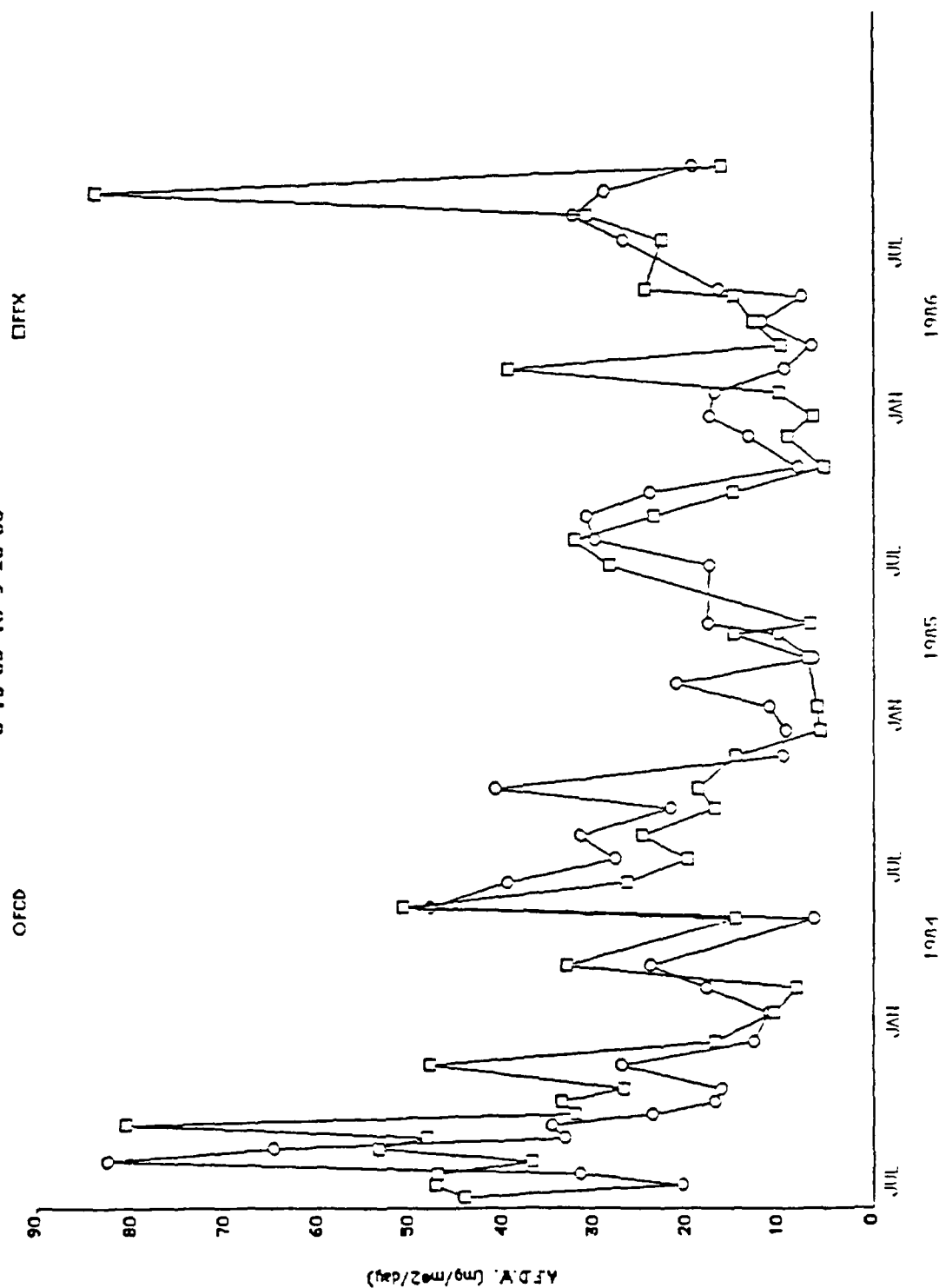


Fig. 2.8 ACCRUAL RATES OF ORGANIC MATTER FOR THE FORD RIVER
10-9-05 10 9-25-06

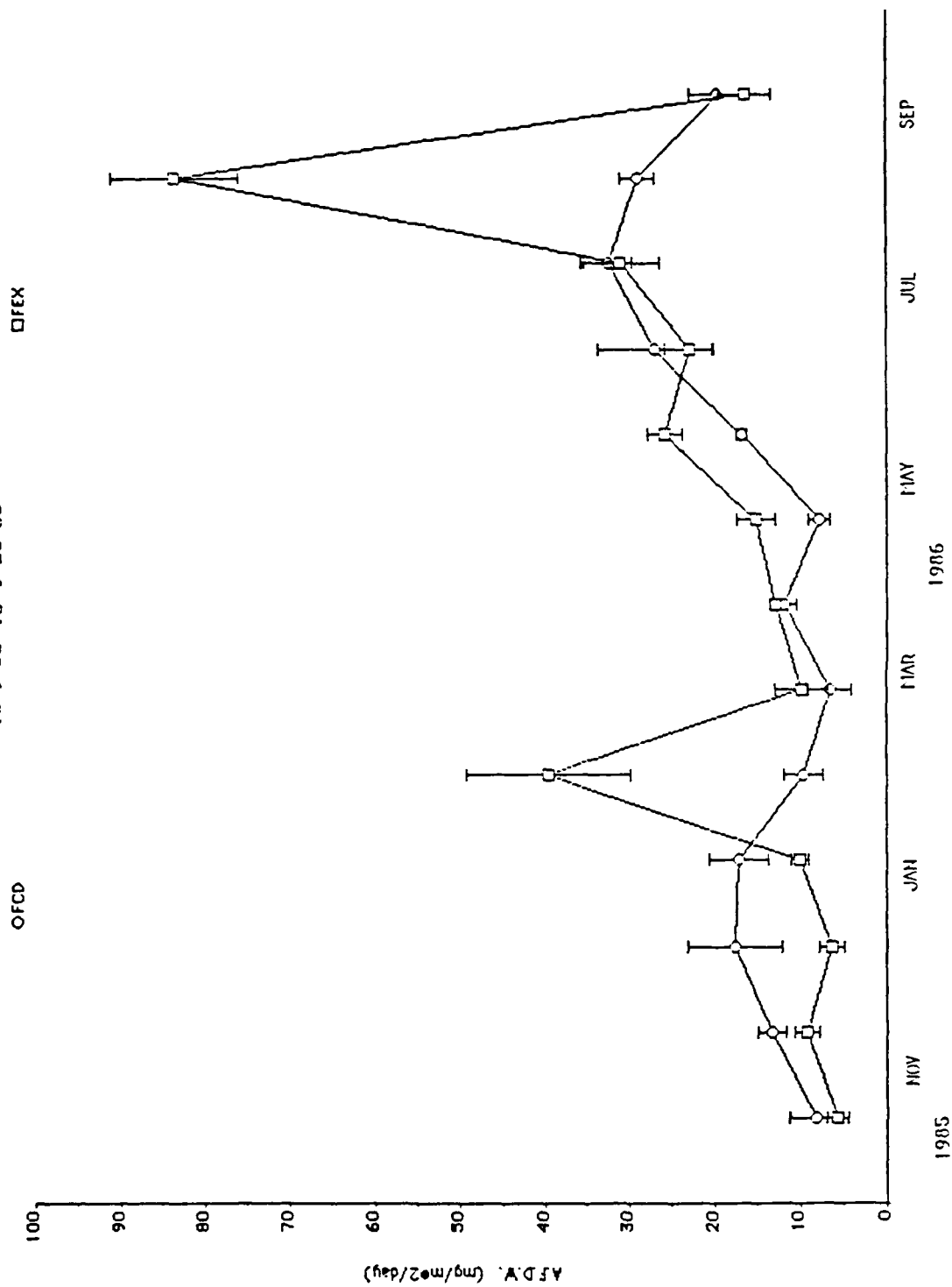


TABLE 2.2 Chlorophyll a to Phaeophytin a Ratios (Values \pm S.E.,
N in Parentheses) for the Ford River

Date out	Days	Control Site (FCD)	Experimental Site (FEX)
10-23-85	29	4.09 \pm 1.67 (10)	4.41 \pm 0.61 (10)
11-13-85	28	4.76 \pm 0.73 (10)	4.92 \pm 0.64 (10)
12-06-85	28	1.82 \pm 0.15 (8)	1.61 \pm 0.16 (8)
1-03-86	28	1.40 \pm 0.16 (10)	1.66 \pm 0.70 (10)
1-31-86	28	1.67 \pm 0.29 (10)	0.82 \pm 0.27 (10)
2-28-86	28	1.64 \pm 0.36 (10)	2.47 \pm 0.48 (10)
3-28-86	28	7.28 \pm 1.57 (8)	4.58 \pm 1.28 (8)
4-25-86	28	18.72 \pm 2.52 (10)	23.88 \pm 8.74 (10)
5-19-86	28	2.01 \pm 0.13 (10)	1.49 \pm 0.17 (10)
6-16-86	28	2.21 \pm 0.19 (10)	4.05 \pm 0.33 (10)
7-14-86	28	313.42 \pm 294.1 (10)	4.33 \pm 0.26 (10)
8-14-86	28	1.73 \pm 0.20 (9)	3.97 \pm 0.40 (9)
9-11-86	28	6.38 \pm 1.16 (7)	4.28 \pm 0.81 (7)

Fig. 2.9 DIATOM CELL DENSITY COMPARISONS

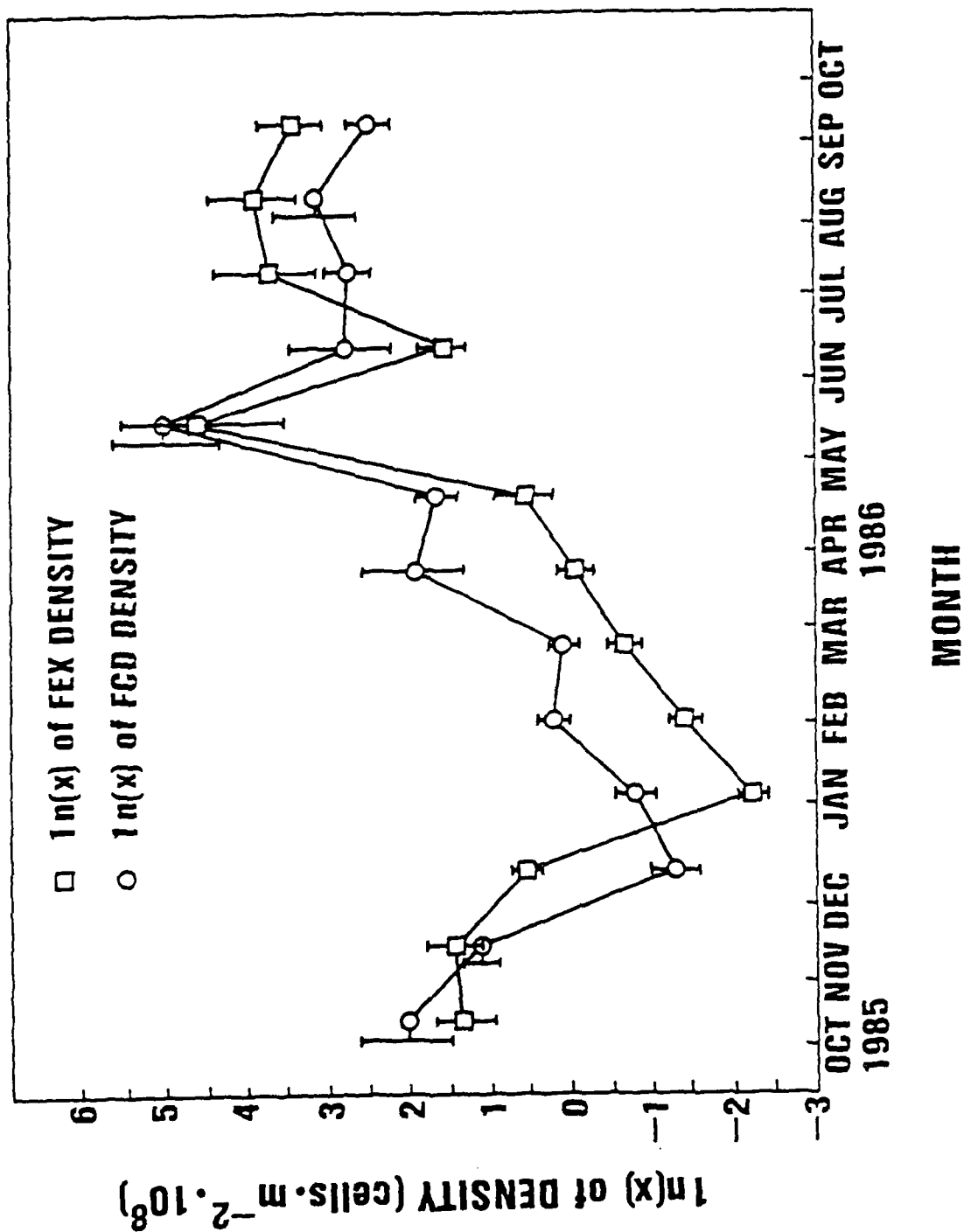


Fig. 2.10 **DIATOM CELL DENSITIES FOR THE FORD RIVER**
6-27-83 to 9-11-86

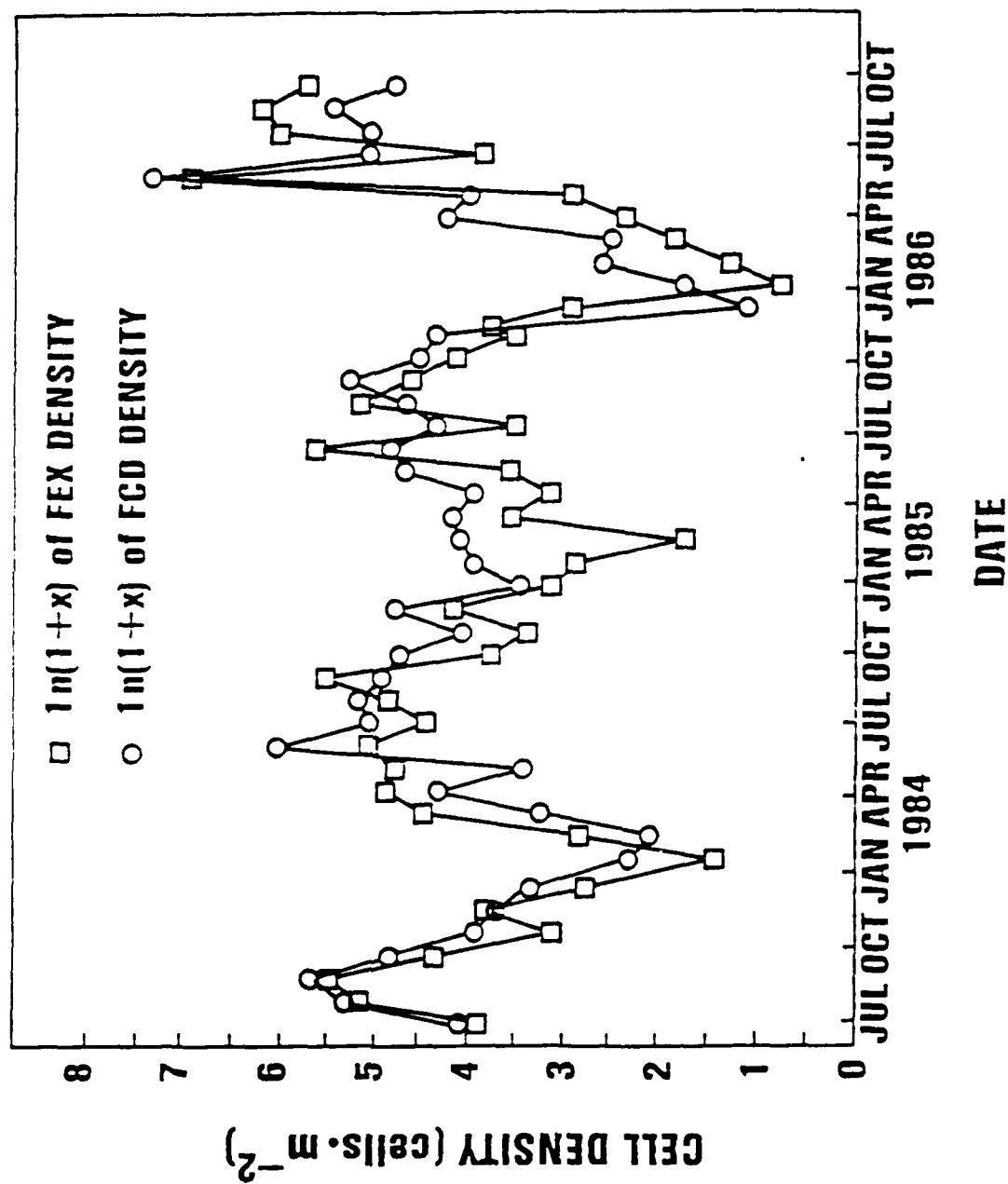


Table 2.3 Cell Density (No. Cells $m^{-2} 10^8$) and Biovolume ($\mu^3 m^{-2} 10^{11}$) for Experimental (FEX) and Control (FCD) Sites for 1985-86. Means \pm SE, N=3.

FEX			FCD	
Date	Biovolume	Density	Biovolume	Density
10-23-85	1.36 \pm 0.57	3.91 \pm 1.36	1.99 \pm 0.87	7.61 \pm 3.32
11-13-85	1.50 \pm 0.32	4.18 \pm 1.20	1.87 \pm 1.07	3.05 \pm 0.73
12-6-85	0.12 \pm 0.02	1.74 \pm 0.03	0.30 \pm 0.08	0.28 \pm 0.09
1-3-86	0.06 \pm 0.02	0.11 \pm 0.01	0.38 \pm 0.07	0.46 \pm 0.12
1-31-86	0.15 \pm 0.04	0.25 \pm 0.06	0.60 \pm 0.12	1.24 \pm 0.63
2-28-86	0.28 \pm 0.07	0.52 \pm 0.05	0.65 \pm 0.04	1.11 \pm 0.08
3-28-86	0.47 \pm 0.10	0.94 \pm 0.21	3.58 \pm 1.06	6.82 \pm 2.17
4-25-86	0.88 \pm 0.12	1.74 \pm 0.94	2.11 \pm 0.14	5.28 \pm 0.59
5-19-86	43.27 \pm 0.70	100.21 \pm 28.38	52.20 \pm 5.08	150.98 \pm 22.34
6-16-86	1.33 \pm 0.17	4.66 \pm 0.51	4.50 \pm 1.35	15.89 \pm 4.23
7-14-86	10.46 \pm 1.26	40.76 \pm 9.04	6.92 \pm 0.58	15.41 \pm 1.62
8-14-86	25.58 \pm 3.65	48.59 \pm 7.41	8.57 \pm 2.92	22.95 \pm 5.51
9-16-86	9.53 \pm 1.50	30.20 \pm 5.98	6.57 \pm 1.04	11.99 \pm 1.70

Table 2.4 Correlations Between Selected Biological Parameters for Control (FCD) and Experimental (FEX) Sites.

Parameter	Correlation Coefficients	SIG.
SPECIES DIVERSITY	.96	P<.01
SPECIES EVENNESS	.50	NS
DENSITY	.89	P<.01
CELL VOLUME	.57	P<.05
BIOVOLUME	.91	P<.01
CHLOROPHYLL a	.96	P<.01
BIOMASS	.67	P<.05

Table 2.5 Regression Results Between Selected Biological Parameters. (All data used for FEX and FCD 1985-86)

<u>REGRESSION</u>	<u>df</u>	<u>Correlation coefficient</u>	<u>Probability</u>
Chlorophyll <u>a</u> with Biovolume	25	.81	P<.001
Chlorophyll <u>a</u> with Density	25	.80	P<.001
Chlorophyll <u>a</u> with Biomass	25	.55	P<.01
Density with Biomass	25	.75	P<.001

of really large peaks in July and August contrasts with chlorophyll *a* (Figs. 2.1, 2.3) and organic matter (Figs. 2.5, 2.7) data. Even so, the degree to which these biological variables matched each other is reflected by the high correlation coefficients obtained when regressing the biological parameters on each other (Table 2.5). The fact that all regressions were highly significant indicates the high degree to which each parameter could explain the regressed parameters variance.

F. Annual Patterns of Species Diversity and Species Evenness

Changes in community composition may reflect the effects of a host of environmental variables, such as changing light levels, increasing or decreasing water currents, or changing water temperatures that may act individually or synergistically to subtly change the abundance of various algal species. Comparing the changes in the periphyton community through the use of a species diversity index coupled with a species evenness index can indicate subtle shifts in community structure unnoticed using other tests, such as chlorophyll *a*, organic biomass levels, or cell densities. Thus, we calculated the Shannon Wiener diversity index (H') and Simpson's Evenness Index (J) for diatom community data. Monthly changes in these two community indices (Figs. 2.11, 2.12; Table 2.6) indicated a general agreement in pattern, with low levels of both indices coinciding with periods of greatest cell density, and high levels of both diversity and evenness coinciding with low overall density as reflected in fall and winter periods. Paired t-tests between sites indicated (Table 2.1) no significant site differences. Correlation coefficients (Table 2.4) indicated that species diversity was more highly correlated between sites ($r=.96$, $p<.01$) than was species evenness.

The dominance of the attached algal community by a few species like *Cocconeis placentula* var. *euglypta* during summer periods of lower current flow and warmer temperatures undoubtedly caused drops in both overall measured diversity and evenness during these periods. When cooler temperatures and increased current flows occurred higher diversity and evenness values were generally recorded, and the attached algal community was in fact not dominated by any one or two very abundant species. The patterns of abundance of this particular species will also be presented in detail elsewhere (see Section H). These patterns in diversity and evenness were also reported for 1983, 1984 and 1985.

G. Annual Patterns of Individual Cell Volume and Total Biovolume

Last year, as more individual cell measurements were completed on the dominant taxa, individual mean cell volumes

Fig. 2.11 SPECIES DIVERSITY COMPARISONS

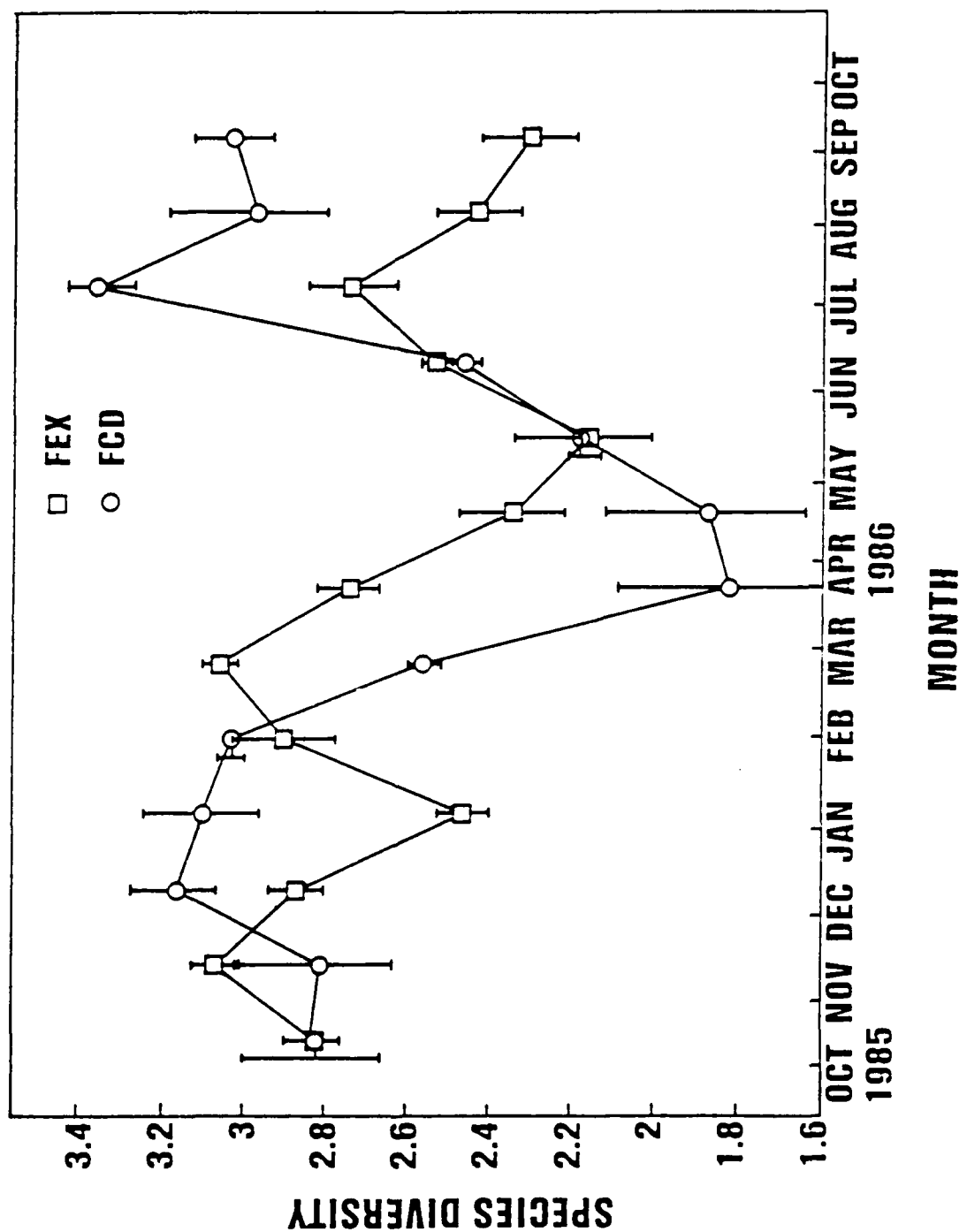


Fig. 2.12 SPECIES EVENNESS COMPARISONS

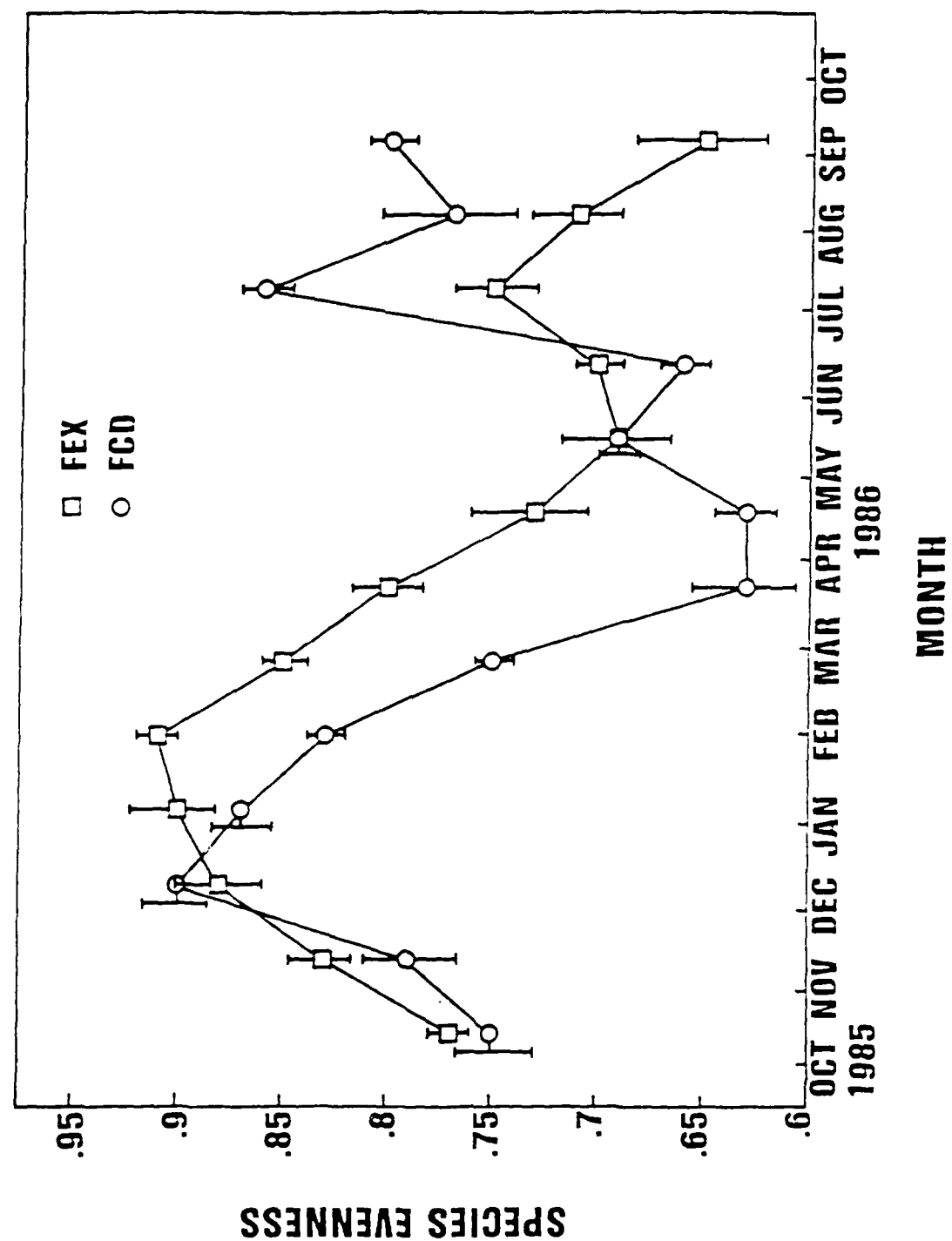


Table 2.6 Species Diversity (H') and Evenness (J) for Experimental (FEX) and Control (FCD) Sites for 1985-86. Means \pm S.E., $N=3$.

FCD			FEX	
Date	Diversity	Evenness	Diversity	Evenness
10-23-85	2.83 \pm .21	0.75 \pm .05	2.82 \pm .09	0.77 \pm .01
11-13-85	2.81 \pm .21	0.79 \pm .04	3.07 \pm .06	0.83 \pm .02
12-6-85	3.16 \pm .11	0.90 \pm .03	2.87 \pm .09	0.88 \pm .03
1-3-86	3.10 \pm .16	0.87 \pm .02	2.46 \pm .09	0.90 \pm .03
1-31-86	3.03 \pm .02	0.83 \pm .01	2.90 \pm .14	0.91 \pm .01
2-28-86	2.56 \pm .05	0.75 \pm .01	3.06 \pm .03	0.85 \pm .01
3-28-86	1.82 \pm .29	0.63 \pm .05	2.74 \pm .09	0.80 \pm .02
4-25-86	1.87 \pm .28	0.63 \pm .02	2.34 \pm .14	0.73 \pm .04
5-19-86	2.18 \pm .09	0.69 \pm .01	2.16 \pm .17	0.69 \pm .04
6-16-86	2.46 \pm .04	0.66 \pm .01	2.53 \pm .03	0.70 \pm .01
7-14-86	3.36 \pm .09	0.86 \pm .01	2.74 \pm .11	0.75 \pm .02
8-14-86	2.97 \pm .24	0.77 \pm .06	2.43 \pm .09	0.71 \pm .02
9-11-86	3.03 \pm .07	0.80 \pm .01	2.30 \pm .13	0.65 \pm .04

were calculated for each of the twenty major diatom species. Length, width, and thickness measurements were used from the light microscope fitted with an ocular micrometer together with measurements from scanning electron micrographs, to allow calculation of morphological cell types according to the closest fitting single geometric figure or set of figures. Volume estimates were multiplied by the density of each species and summed to provide an accurate picture of total biovolume for all cells present. The 1986 diatom data were converted to a total biovolume estimate (Fig. 2.13; Table 2.3). Paired t-tests between sites indicated no significant differences in untransformed data (Table 2.1). Correlations between sites for diatom biovolume indicated a highly significant relationship (Table 2.4, $r=.91$, $p<.01$). Regression results (Table 2.5) also showed that significant amounts of the variability in chlorophyll a were accounted for by the variability in biovolume ($r=.81$, $p<.001$) estimates.

Biovolume estimates between sites in 1985 (see 1985 annual report) indicated that FCD diatoms were significantly larger in total biovolume than were the diatoms of the experimental site. In 1986, no significance was found between sites (paired t-test, Table 2.1) using the actual biovolume estimates. Differences were significant using natural log transformed data. The control site, thus, may have slightly more diatom biovolume than the FEX site, or perhaps biovolume is simply more variable at the control site.

Mean individual cell volume was also calculated (Fig. 2.14; Table 2.7). The reduced cell density in winter months (Table 2.3, Fig. 2.9) coincided with the highest mean individual cell volume (Fig. 2.14, Table 2.7). Cell volumes in December ranged from 800 to 1,150 cubic microns per individual. In the periods of greatest numerical cell density, cell volumes only averaged 200-500 cubic microns. This trend was also observed in 1985 and reported in last years annual report. Individual comparisons between sites (Table 2.1) indicated no significant difference between sites. Correlations between sites (Table 2.4) for cell volume were also significant, indicating an overall agreement between sites, similar to results presented in the last annual report.

H. Before and After, Control and Impact (BACI) Analysis

Our current methods for analysis of "before" and "after ELF effects", as reported in last year's annual report, include a traditional 3-way analysis of variance. The variables include a year, site and selected factors for analysis. While these analyses may prove to be the most statistically robust of several available, they may suffer from a lack of true replication or "pseudoreplication" (Hurlbert 1984). Thus, to consider the validity of such questions, and to remove ourselves from a single methodology, we have analyzed our data according to the new techniques of Stewart-Oaten et al. (1986).

Fig. 2.13 TOTAL BIOVOLUME COMPARISONS

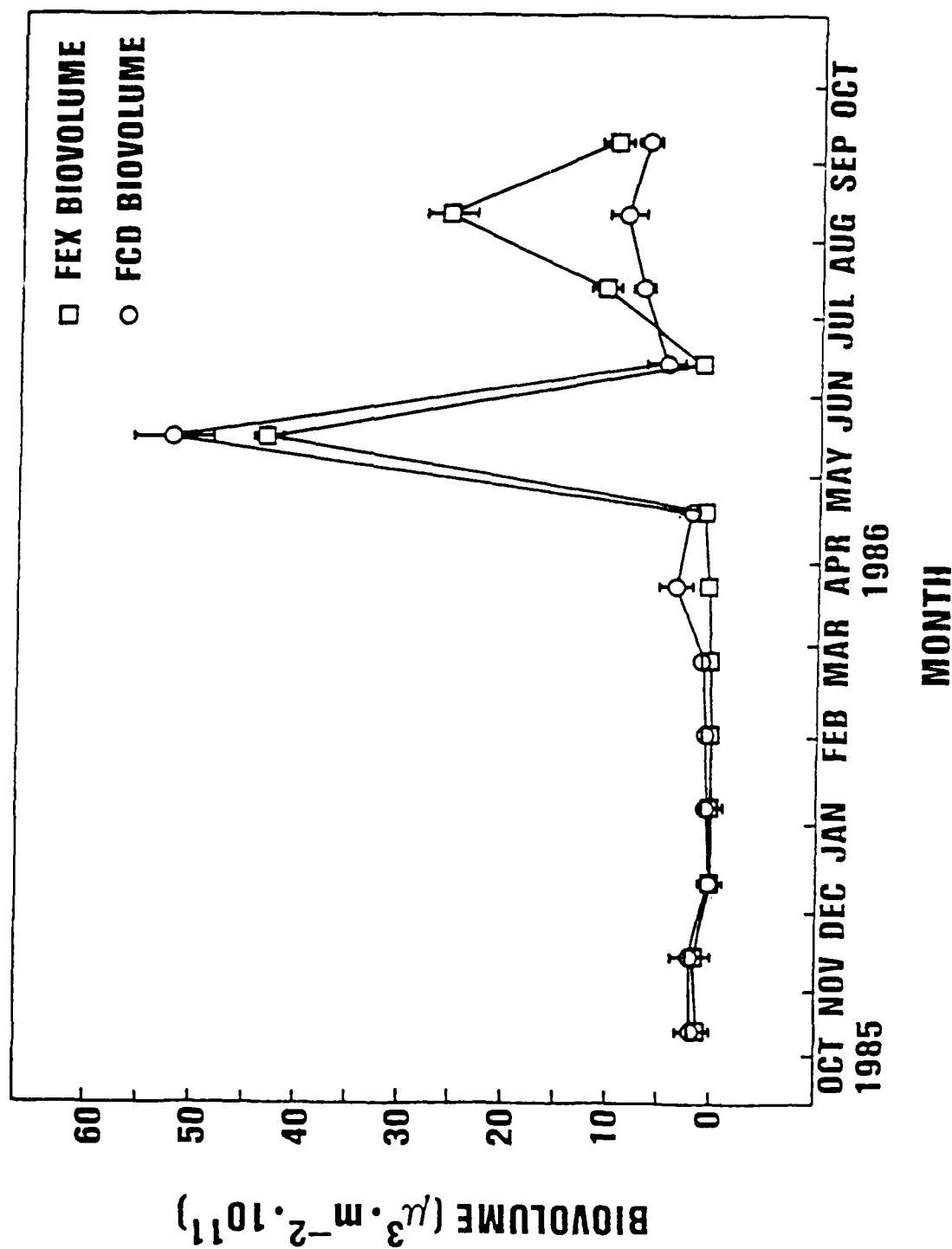


Fig. 2.14 **INDIVIDUAL CELL SIZE COMPARISONS**

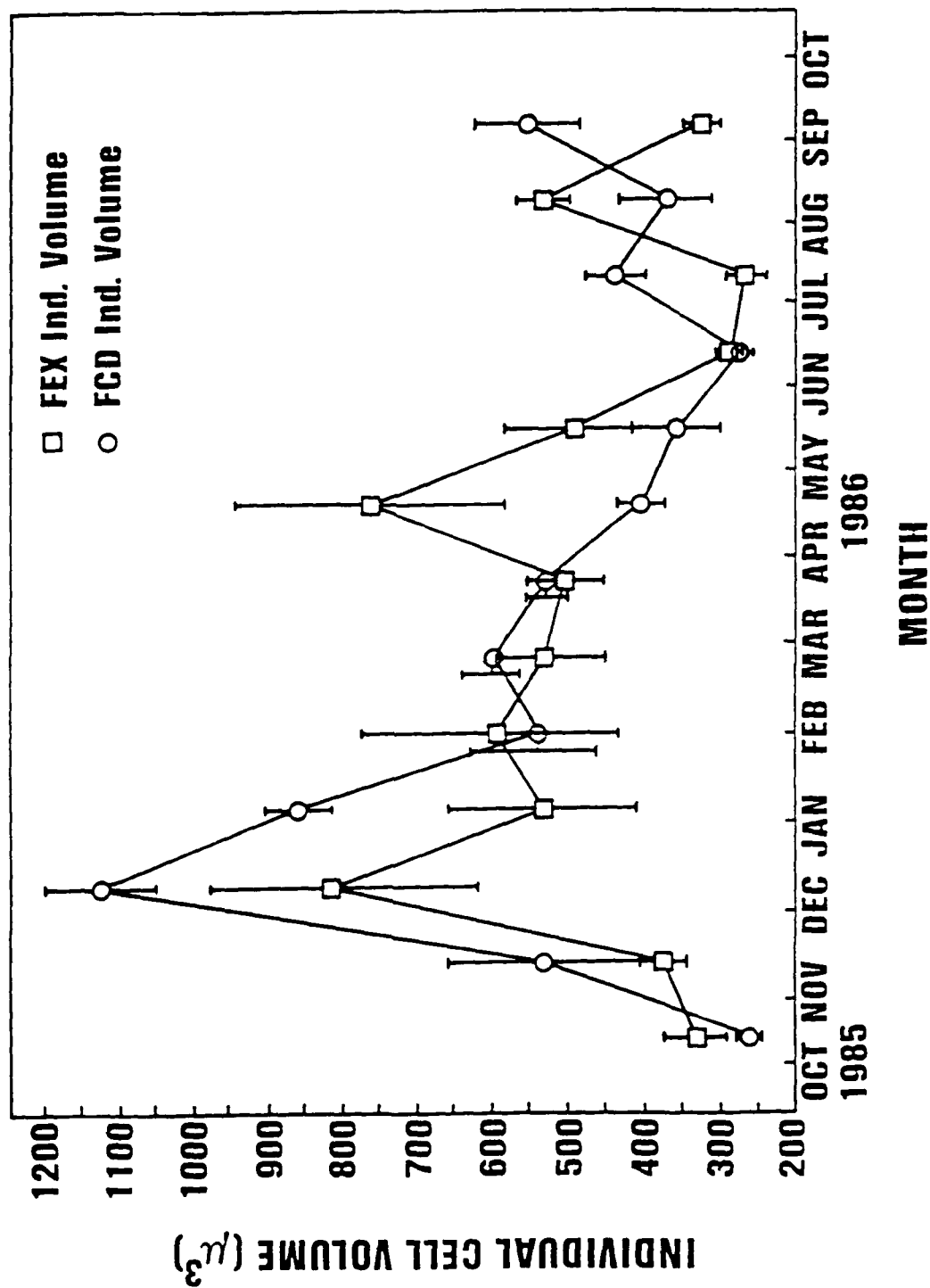


Table 2.7 Mean Individual Diatom Cell Volume (μ^3)
for Experimental (FEX) and Control (FCD) Sites
for 1985-86. Means \pm SE, N=3.

DATE	FEX	FCD
10-23-85	330.37 \pm 49.60	261.02 \pm 4.13
11-13-85	375.63 \pm 31.74	529.52 \pm 211.41
12-6-85	816.47 \pm 273.42	1,127.10 \pm 132.69
1-3-86	529.04 \pm 157.69	861.09 \pm 53.32
1-31-86	593.66 \pm 183.98	538.23 \pm 102.85
2-28-86	529.68 \pm 78.51	596.65 \pm 43.69
3-28-86	504.38 \pm 46.98	527.54 \pm 38.55
4-25-86	764.07 \pm 254.58	404.43 \pm 25.46
5-19-86	490.09 \pm 108.56	355.98 \pm 43.38
6-16-86	285.00 \pm 9.07	274.58 \pm 18.46
7-14-86	267.44 \pm 29.97	438.43 \pm 41.54
8-14-86	532.49 \pm 37.75	369.74 \pm 60.75
9-11-86	323.42 \pm 20.27	551.61 \pm 64.34

Fig 2.15 COCCONEIS ABUNDANCES
1983 - 1984

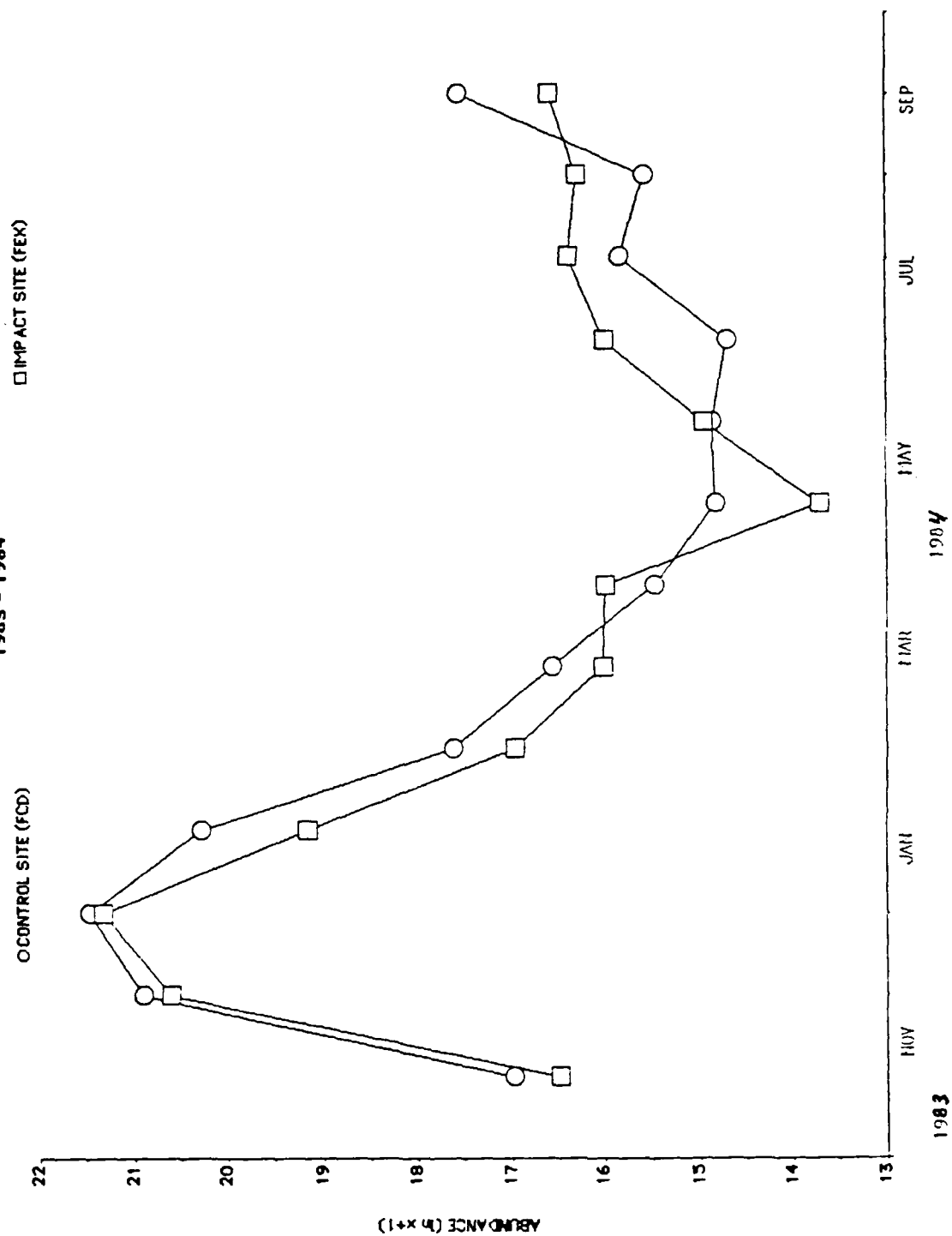


Fig 2.16 COCCURENIS ABUNDANCES
1984 - 1985

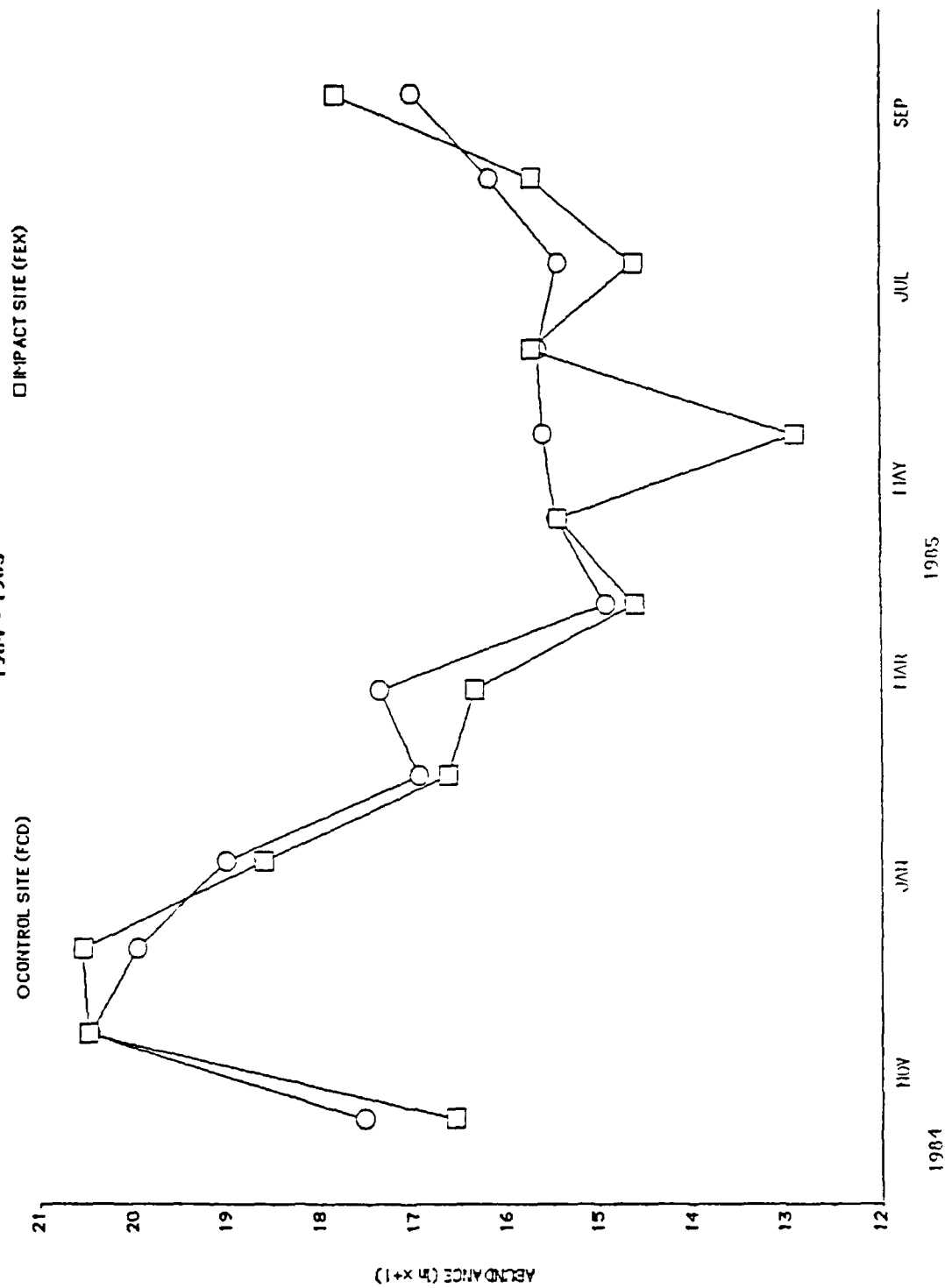


Fig. 2.17 DIFFERENCES IN COCCUREIS ABUNDANCE
1983-84 vs. 1984-85

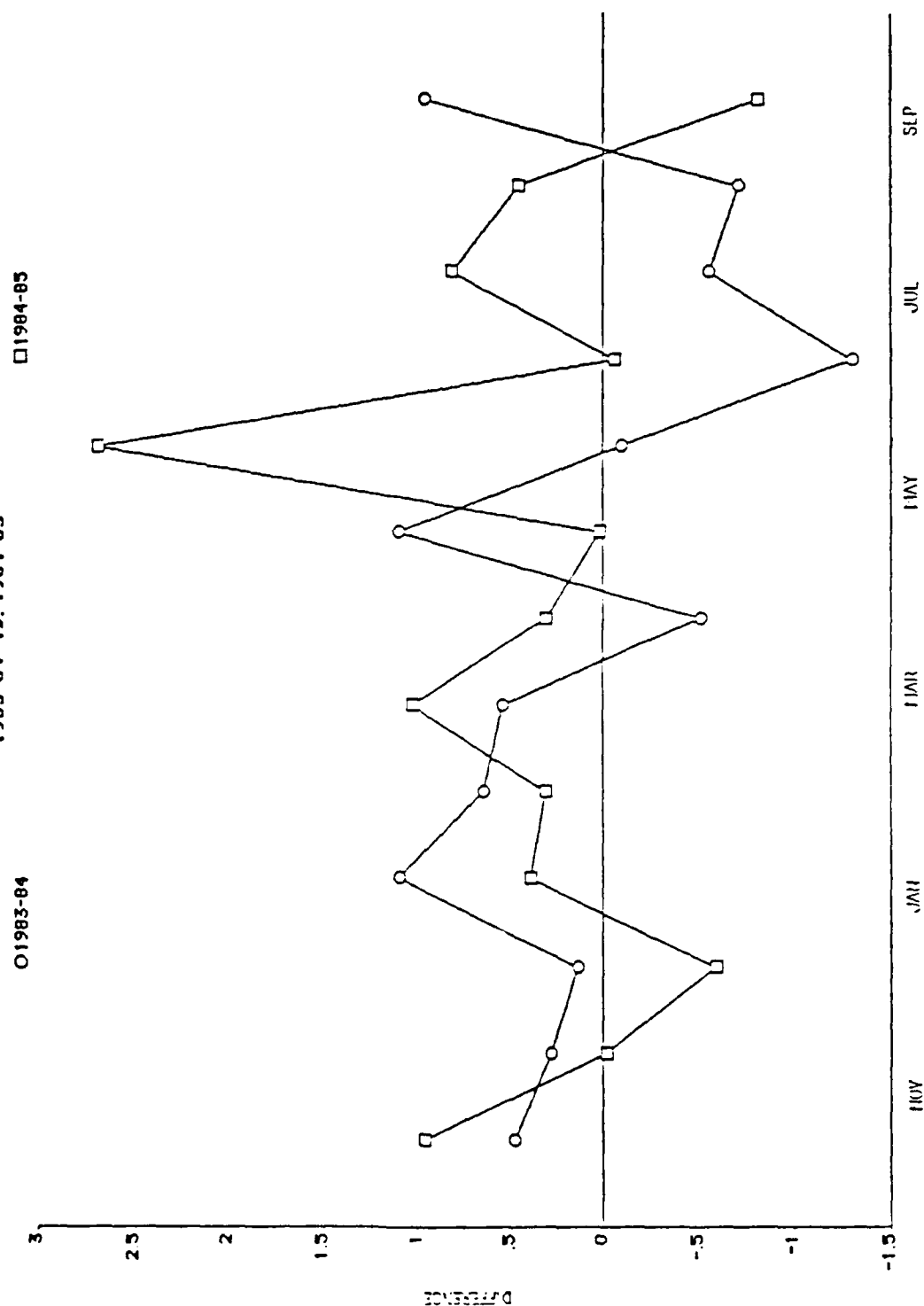
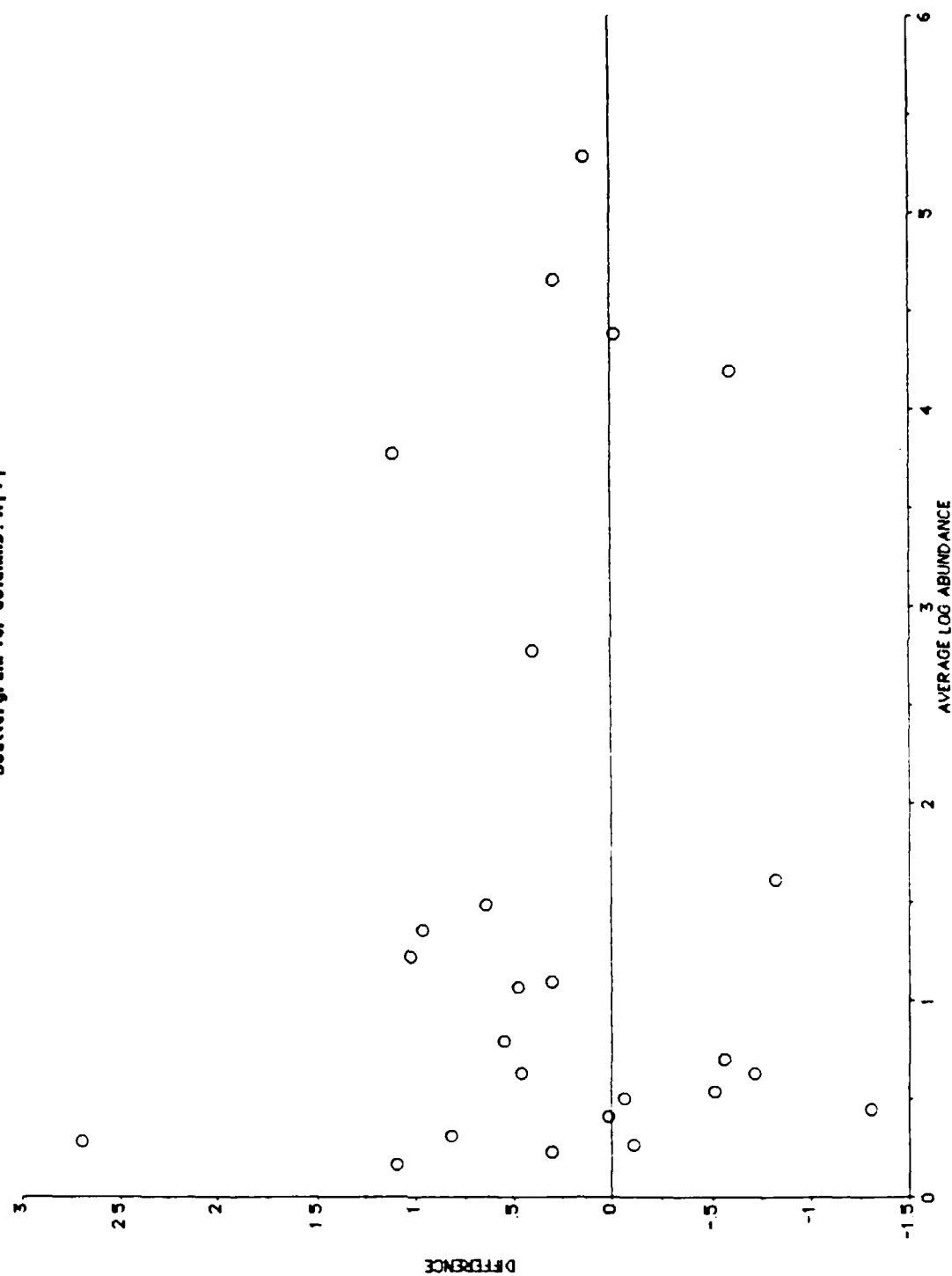


Fig. 2.18 DIFFERENCES IN COCCONEIS ABUNDANCE VS. TOTAL ABUNDANCE
Scattergram for columns: X1 Y1



The methods discussed and presented by Stewart-Oaten et al. (1986) are intended to meet Hurlbert's objections (Hurlbert 1984) concerning the appropriate design of sampling programs to assess biological impacts at a single point. The design requires replicated sampling in time. Before and After the antenna is operating at both Control and Impact sites (the BACI design).

The key step in determining the statistical appropriateness of the test used to assess impacts on the abundance of biological populations is to first correctly identify the parameter of interest, which is "the mean of the underlying probabilistic 'process' that produces the abundance itself" (Stewart-Oaten et al 1986).

In the BACI test, Impact (FEX) and Control (FCD) sites are sampled simultaneously with each sampling time acting as a replicate. Only a single point is used to represent a sampling time and that is the difference between the Impact and Control samples for that time. By plotting this difference between sites for each sampling time throughout a year, a difference curve for each population's abundances can be determined. The analysis is used to detect whether the variability about this curve of abundance differences for the two sites changes significantly after the antenna is switched on.

Data used for presentation was taken from year 1983 through 1985, to provide the longest complete set currently available. As further data and subsequent analyses of individual species abundances ultimately become available, a complete picture covering 1983 through 1989 Before data will be contrasted with the 1989-91 After data. Figure 2.15 and Figure 2.16 are plots of the log of the abundance values for Cocconeis placentula var. euglypta for 1983-84 and 1984-85, respectively at control (FCD) and impact sites (FEX). In this instance, we can consider 1984-85 as an "impact" year for demonstration purposes only. Subtracting the abundances for each year generates figure 2.17, the curve of differences between the two sites for the two time periods. To test for additivity, the log (abundance +1) is plotted against the differences (Figure 2.18). The test for zero slope in the regression of differences against averages, which in this case is equivalent to Tukey's test for additivity was nonsignificant ($p=0.72$). Once additivity and independence are plausible assumptions, and satisfy the tests, a standard two sample t-test can be used on the differences to determine if there is an antenna effect. In this case, a paired t value of 0.77 ($p=0.46$) indicated that no significant changes had occurred in the abundance differences between the two time periods.

We feel that this type of analysis is very promising for testing ELF effects. Ultimately, we expect to use it on selected diatom species as well as many of the community parameters presented heretofore. Another bonus of using this

test is that we examined individual species data more closely than had previously been the case. The Cocconeis data are less variable than overall community parameters such as chlorophyll a. Thus, we expect to use more of this type of data in future, more detailed analysis.

I. Effects of Environmental Variables on the Periphyton Community

A series of multiple regressions were calculated for the June 1983 to June 1985 data sets for each site to examine possible relationships between environmental variables and periphyton community parameters. These regressions were reported in the last annual report and were not repeated in 1986. They will be recalculated after compilation of another year's data. Basically, the 1985 results were as follows. The multiple regression of chlorophyll a at FCD with above water solar photosynthetically active radiation (PAR), water temperature, and discharge resulted in excellent predictive capability for this parameter ($R^2=0.89$, $p<0.001$). Addition of dissolved oxygen and underwater PAR to this equation only increased the predictive power slightly ($R^2=0.91$, $p<0.01$). High correlation coefficients between water temperature and chlorophyll a from correlation matrix analyses led us to suspect that it was the driving variable since it was highly negatively correlated with discharge ($R^2=-0.91$ at both FEX and FCD), and with dissolved oxygen ($R^2=-0.98$) at both FEX and FCD). It was also significantly negatively correlated with above water PAR ($R^2=-0.49$ at both sites). However, temperature alone proved to be a less robust predictor of chlorophyll a in regression analysis than did the multiple regressions with PAR, temperature, and discharge ($R=0.77$, $p<0.01$ at FCD, $R=0.53$, $p<0.1$ at FEX). Multiple regression analyses of organic matter biomass resulted in no significant equations for either site when regressed against ambient monitoring parameters. The same was true for cell density.

One of the reviewers for the last annual report suggested that data transformation might be in order before calculating correlation coefficients. We performed several transformations before calculating correlation coefficients for the 1985-86 data (Tables 2.8-2.10). Water temperature was the factor correlated with chlorophyll a regardless of transformation. No transformation significantly improved this relationship. An e^x transformation resulted in much better correlations for alkalinity, hardness and a slightly better correlation for water temperature and chlorophyll a than was true for untransformed data (Table 2.8). However, correlations between chlorophyll a and the biological factors fell apart with this transformation. A $\ln(X+1)$ transformation resulted in correlations similar to those obtained for untransformed data when chlorophyll a was correlated with physical or chemical factors and better correlations between chlorophyll a and the other biological factors (Table 2.8). Most correlations

Table 2.8 Correlation Coefficients for Chlorophyll a Data with Various Transformations*

Parameter	Untransformed Data	e^x transformed Data	1/x transformed Data	Ln(X+1) Data
Alkalinity	0.68	0.98	NS	0.67
Hardness	0.58	0.84	NS	0.55
Sus. Solids	NS	NS	NS	-0.51
Diss. Solids	0.42	NS	NS	NS
Diss. Oxygen	-0.77	NS	-0.50	-0.84
Water Temperature	0.80	0.83	0.65	0.79
Conductivity	0.73	NS	NS	0.70
Turbidity	NS	NS	NS	NS
Diatom Cell Density	0.56	NS	0.96	0.89
Diatom Total Biovolume	0.58	NS	0.93	0.89
Diatom Mean Ind. Cell Volume	NS	NS	-0.46	-0.41
Diatom Diversity	NS	NS	NS	NS
Diatom Evenness	NS	NS	-0.62	-0.48
Organic Matter Standing Crop	0.55	NS	0.42	0.72

*All values reported are significant at $p < 0.05$.

Table 2.9 Correlation Coefficients for Organic Matter Standing Crop
(AFDW) Data with Various Transformations*

Parameter	Untransformed Data	e^x transformed Data	1/x transformed Data	$\ln(X+1)$ Data
Alkalinity	NS	NS	0.51	0.51
Hardness	NS	NS	NS	NS
Sus. Solids	NS	NS	-0.40	-0.41
Diss. Solids	NS	NS	0.45	NS
Diss. Oxygen	-0.55	NS	-0.65	-0.69
Water Temperature	0.60	NS	0.66	0.75
Conductivity	0.40	NS	0.49	0.52
Turbidity	NS	NS	NS	NS
Diatom Cell Density	0.76	NS	NS	0.79
Diatom Total Biovolume	0.74	NS	0.54	0.78
Diatom Mean Ind. Cell Volume	-0.41	NS	-0.48	-0.50
Diatom Diversity	-0.39	NS	NS	NS
Diatom Evenness	-0.54	NS	-0.40	-0.52
Organic Matter Standing Crop	0.55	NS	0.42	0.72

*All values reported are significant at $p < 0.05$.

Table 2.10 Correlation Coefficients for Diatom Density Data with Various Transformations*

Parameter	Untransformed Data	e^x transformed Data	1/x transformed Data	$\ln(X+1)$ Data
Alkalinity	NS	NS	NS	0.49
Hardness	NS	NS	NS	NS
Sus. Solids	NS	NS	NS	-0.46
Diss. Solids	NS	NS	NS	NS
Diss. Oxygen	NS	NS	-0.41	-0.69
Water Temperature	0.40	NS	0.54	0.79
Conductivity	NS	NS	NS	0.54
Turbidity	NS	NS	NS	NS
Diatom Cell Density	0.56	NS	0.96	0.89
Diatom Total Biovolume	0.98	1.00	0.89	0.98
Diatom Mean Ind. Cell Volume	NS	NS	NS	-0.54
Diatom Diversity	-0.48	NS	NS	-0.43
Diatom Evenness	-0.45	NS	-0.52	-0.66
Organic Matter Standing Crop	0.76	NS	NS	0.79

*All values reported are significant at $p < 0.05$.

between chlorophyll a and physical or chemical factors fell apart with a $1/X$ transformation but correlations with biological factors were highly enhanced (Table 2.8). These same type of results were characteristic of correlations for both organic matter standing crop (Table 2.9) and diatom cell density (Table 2.10). It may be that we will need to transform some data but not others prior to analyses. However, an overall correlation matrix appears to be as robust using untransformed data as any transformation tried in this analysis. We also suspect that many of the periphyton parameters are determined by cumulative PAR exposure or may be determined by degree days, etc. Thus, this type of analyses will be examined in future reports.

We also calculated some stepwise regressions in 1986. A stepwise regression for chlorophyll a and the ambient monitoring parameters for 1986 indicated that water temperature explained 61% of variance and was followed in importance by conductivity of water (33%). Water temperature was also the most important factor for organic matter standing crop but only accounted for 36% of variability followed by dissolved oxygen and water temperature (neither of the last two were significant). Organic matter biomass explained 55% of variance in diatom cell density followed by chlorophyll a. None of the eight physical or chemical variables entered in this stepwise regression were very important in explaining variance in cell density. This agrees with the correlation analyses (Table 2.10) where only water temperature of the physical and chemical variables was weakly correlated with density.

Certainly, the results relating ambient monitoring data to biological variables lead us to the conclusion that fewer variables need be monitored. Most of the field monitored variables are not that time consuming with the exception of suspended and dissolved solids. We may choose to delete these parameters in the future. We performed no new regression or correlation analyses between nutrient (N,P,K,Si) and biological variables this year. Some weak correlations between N and P and the biological variables were reported in 1985. Thus, we expect to continue these analyses in 1987.

J. Photosynthesis - respiration ratio studies (P/R)

A separate study was undertaken to evaluate primary production using short term changes in dissolved oxygen gas concentrations during the summer period of intense algal growth. The dissolved gas procedures are advantageous because estimates of community primary productivity, gross productivity, and community respiration may be obtained with one technique (Bott et al. 1979). Rocks from the stream bed were placed inside each of six plexiglass chambers occupying $1/3$ to $1/4$ of the total chamber volume (3-4 L). Three light and three dark chambers were run simultaneously on each date. Recirculated water was continuously recycled through

submersible pumps. Each test lasted from 0.5-2.0 hours between 1000-1300 hours of each test day in 1984. One site was tested during one week, and the second was tested during the following week in 1984. Even though 1984 results indicated no significant difference (t-test) between sites for net production, respiration, or gross production, the relatively large standard deviations led us to change procedures somewhat for 1985. During 1985 and 1986, both FCD and FEX were tested on the same day with the test at each site lasting one hour. Tests were begun at one site at 1000 hours and were completed at the other site by 1400 hours. Alternate sites were tested first in alternate weeks.

The assumptions made for the purposes of production calculations considered algal periphyton to occupy only the upper surface half of each rock. Surface area was, therefore, determined by wrapping each rock in aluminum foil, straightening the foil, and determining the area using a leaf area meter (LI-COR). Production estimates per mg of chlorophyll a per meter square of rock surface were also calculated after subjecting the rocks with attached periphyton to chlorophyll a extraction.

Gross and net primary production and respiration were very similar between the control (FCD) and experimental (FEX) sites in 1986 (Table 2.11). As had been true in 1984 and 1985, there were no significant differences (paired t-tests) between sites for any of the parameters in 1986. The modified procedures used in 1985 and 1986 resulted in lower standard deviations for each parameter and in additional convergence of mean values between sites compared to 1984. Differences between years were not very great for these parameters suggesting that this community based comparison offers a robust means for detection of possible ELF effects once the antenna goes operational.

K. Summary

1. Chlorophyll a

Annual patterns for chlorophyll a standing crop and accrual were characterized by considerable year-to-year variability. The only consistency between data for 1986 and data for the two previous years was a July-August peak and winter lows. The summer peak varied in magnitude between years but always occurred. In 1986, no site differences were detected ($p < 0.05$) between FCD and FEX for chlorophyll a. Differences had occurred in 1983 and 1984 but not in 1985. This lack of intersite difference in 1985 and 1986 coupled with use of 3-way ANOVA analyses or the new BACI technique described in this report suggest that this parameter can be used to detect differences which may occur between sites once ELF exposure begins.

TABLE 2.11 HOURLY PRODUCTION AND RESPIRATION RATES
FOR ROCK SUBSTRATES OF THE FORD RIVER

DATE	NET PRIMARY PRODUCTION		RESPIRATION *		GROSS PRIMARY PRODUCTION **	
	mg O ₂ /mg chl a/m ²	mg O ₂ /m ²	mg O ₂ /mg chl a/m ²	mg O ₂ /m ²	mg O ₂ /mg chl a/m ²	mg O ₂ /m ²
			FORD CONTROL	SITE (FCD)		
6-18-86	8.64	112.62	1.06	27.83	6.96	140.51
6-25-86	6.44	95.90	3.68	6.26	5.84	102.16
7-2/-6	3.92	58.39	5.19	40.25	5.58	98.64
7-9-86	7.37	124.90	5.46	47.61	9.38	172.51
7-22-86	5.52	59.87	3.94	39.10	8.68	99.00
7-24-86	5.33	71.48	1.87	23.39	7.31	94.87
7-30-86	3.44	79.68	1.41	37.26	4.79	116.94
8-12-86	4.66	71.11	5.69	34.19	5.94	105.30
8-21-86	3.9	62.64	5.84	39.08	5.24	101.71
8-28-86	4.75	84.19	1.00	17.35	5.38	101.54
Ave ± S.D.	5.40 ± 1.66	82.08 ± 22.69	3.51 ± 2.01	31.24 ± 12.50	6.51 ± 1.54	113.32 ± 24.67
			FORD EXPERIMENTAL SITE (FEX)			
6-18-86	7.10	103.20	4.49	47.23	9.67	150.43
6-25-86	4.86	67.20	0.44	4.49	5.26	70.69
7-2-86	6.39	73.65	1.77	21.08	7.90	94.74
7-9-86	4.44	77.80	2.27	24.75	5.49	102.55
7-22-86	6.00	111.10	5.14	42.88	10.91	154.00
7-24-86	41.34	112.20	3.95	46.91	12.49	158.12
7-30-86	2.60	49.79	3.57	63.95	5.58	113.74
8-12-86	6.40	102.60	1.63	33.96	7.35	163.74
8-21-86	8.00	121.97	5.18	41.76	10.25	31.16
8-28-86	1.17	32.88	-0.36	1.73	1.76	
Ave ± S.D.	8.83 ± 11.61	85.24 ± 29.59	2.81 ± 1.95	32.52 ± 20.42	7.70 ± 3.29	117.57 ± 43.42

*= Gross Respiration of Entire Microbial Community (Bacteria and Algae)

**= Total Metabolism = Respiration + Net Primary Production

2. Organic Matter

Organic matter standing crop and accrual rates showed considerable year to year variability as had chlorophyll a. These parameters have consistently been characterized by no significant differences between sites since the start of the project in 1983. This trend continued in 1986. The only year to year consistency has been a July-August peak in standing crop and accrual rates and winter lows.

3. Chlorophyll a to Phaeophytin a Ratios

This ratio continued to vary widely throughout the year in 1986. It is not a useful parameter for detection of ELF effects.

4. Diatom Cell Density

Diatom cell density continued to be characterized by no statistical differences between sites ($p < 0.05$). Trends in cell density do not include a July-August peak. Instead, individual numbers tend to be high throughout the summer with some tendency towards a June peak. Conversely, individual cell volume tends to be higher in the winter while numbers are low.

5. Species Diversity and Evenness

Diatom species diversity and evenness was not significantly different between FEX and FCD in 1986 continuing the trends established in 1983, 1984 and 1985. Annual trends continued to be characterized by high diversity and evenness during winter with lower values during the summer.

6. Total Biovolume and Individual Cell Volume Studies

Individual cell volumes of the 20 dominant diatom species were not significantly different between the experimental and control sites. Total biovolume was significantly larger at the control site than at the experimental site as had been true in 1985.

7. Before and After, Control and Impact (BACI) Analyses

Stewart-Oaten et al. (1986) developed this procedure for just the type of analyses we are conducting. We illustrate the procedure by comparing 1983-84 ("before") data for Cocconeis to 1984-85 ("after") data. No significant changes between years were detected. This procedure will be used for both species and community level analyses in our final report.

8. Correlation with Environmental Variable

Correlation matrices were calculated using variously

transformed data. No single transformation appears to give an overall better correlation than does untransformed data. However, certain transformations appear to enhance correlations between biological and physical variables while other transformations enhance correlations between the various biological parameters. Stepwise regressions were also calculated in 1986 and continued to emphasize the importance of water temperature in explaining variance in much of the biological data.

9. Photosynthesis-Respiration Studies

Net production, respiration, and gross production of the community on rock surfaces did not differ significantly between FEX and FCD in either 1984, 1985 or 1986. These measurements appear to offer a precise means of detecting ELF effects on community metabolism.

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Diatom colonization dynamics in a lotic system

Mark P. Oemke¹ & Thomas M. Burton²

¹Department of Zoology, Michigan State University, E. Lansing, MI 48824, USA

²Departments of Zoology and Fisheries and Wildlife, Michigan State University, E. Lansing, MI 48824, USA

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Abstract

A series of three overlapping sets of slides were exposed in riffle and pool habitats in a fourth order river in the Upper Peninsula of Michigan. Each set was exposed for 6-8 weeks and overlapped the preceeding set by 2 weeks. Diatom cell densities and community structure were determined after daily or weekly exposure periods for each set. The first set was placed on August 4, 1982, and the third set removed on October 16, 1982. Species diversity and evenness peaked quickly during colonization. Both indices decreased as the length of exposure increased. Early colonizing diatom species that occasionally accounted for large proportions of the total diatom community were soon replaced by other diatom species that tended to persist through time. Major dominant species were well established by day 28. Severe net cell losses (up to 17% of the total density) were recorded after only an 8-9 day exposure in both pools and riffles. Pool slides showed greater cell densities during the first few day's exposure than did slides exposed in riffle zones. After this brief conditioning period, however, the riffle slides showed more rapid cell growth and/or accumulation rates. Mean cell densities were similar between pool and riffle slides after 6-8 week exposures.

Seasonal changes appeared to strongly influence diatom species succession. Seasonal changes in water velocity, temperature, or light may have the same effect as the more dramatic flood events which reset periphyton to earlier successional stages, resulting in increased major changes in species composition of the periphyton diatom community.

Introduction

The recovery of the periphyton community in streams following natural phenomena such as floods or after environmental perturbations associated with pollution events is an important determinant of overall stream productivity. Energy flux in many middle order streams (orders 4-7) is dominated by autotrophic production by the periphyton community (Vannote *et al.*, 1980). Thus, the colonization of freshly scoured substrates by periphyton may be especially important in these streams in determining rates and patterns of secondary production. Artificial substrates are often used to measure periphyton community structure and rates of production. Therefore, understanding

the colonization pattern and process is essential for understanding energy flux and for relating data derived from artificial substrates to natural substrate phenomena in these middle order rivers.

Exposure duration has been shown to be an important determinant of accumulation rates and species community structure for both lentic (Hoagland, 1983; Hudson & Bourget, 1981; Hoagland *et al.*, 1982) and lotic waters (Cattaneo *et al.*, 1975; Dickman & Gochner, 1978; Gale *et al.*, 1979; Stevenson, 1984). Exposure periods ranging from 14 days (Patrick *et al.*, 1954; Castenholz, 1960) to one month (Brown & Austin, 1971; Lowe & Gale, 1980) have been recommended for artificial substrates for sampling the equivalent of the 'mature' community occurring on natural substrates in

the stream. Such fluctuating conditions as current velocity and nutrients (Patrick & Reimer, 1966; Patrick, 1967; Reisen & Spencer, 1970; Horner & Welsh, 1981; Stevenson, 1983) as well as temperature and light (Kevern & Ball, 1965; Patrick, 1971) influence rate and pattern of colonization and suggest that a standard exposure period applicable to all streams may not exist. The length of time before a mature community develops on any artificial substrate may change considerably from lake to lake or stream to stream. Diatoms colonize new substrates within 2 hours and measurable populations occur within 7–14 days or earlier (Tuchman & Blinn, 1979; Hoagland, 1983). After the first 7–14 days of rapid colonization, competition for substrate surface intensifies and accumulation rates increase (Hoagland *et al.*, 1982). Thus, both space and time appear to be important determinants of periphyton community structure.

In 1982, a study of periphyton colonization was initiated for the Ford River, a fourth order stream in Michigan's upper peninsula. The objectives of this study were: (1) to document changes in diatom species composition, diatom cell densities, and diatom species evenness and diversity that occurred during succession over daily, weekly, monthly and seasonal time scales; (2) to determine when sampling of artificial glass slide substrates would show the most consistent diatom community, and; (3) to determine seasonal effects on colonization rates and patterns.

Materials and methods

Plexiglass slide racks were designed to hold 8 standard 7.6×2.5 cm glass slides in a vertical placement oriented parallel to the current in the river. These slide racks were fastened to bricks and placed in pool and riffle habitats at a site in the Ford River. Slides were removed after different exposure periods ranging up to 56 days. Any site specific temporal variability was separated into short term temporal variability by removing samples daily for eleven days and into long term temporal variability by sampling weekly for 6–8 weeks. Seasonal temporal changes in community dynamics were assessed by using three overlapping experiments each started 2 weeks later than the preceding one. The three 6–8 week overlapping

sets provided data on diatom community dynamics continually from the high temperatures and low water levels of summer through the colder temperatures and rising water levels of autumn. The pool zones and riffle zones were sampled separately to keep potentially different community colonization data distinct as discussed by Blum (1960), Busch (1979), and Fischer (1983). Areas of fast current in riffle zones less than 20 cm deep and in nearby pools 50–100 cm deep were sampled at a single site within 30 m of each other.

For species composition and cell count determinations, two slides were removed on each sampling period from each pool or riffle habitat. One slide was air dried and the other placed in either a mixture of 6 parts water, 3 parts 95% ethanol and 1 part formalin (6:3:1) or 4% glutaraldehyde. Glutaraldehyde was less disruptive to algal cellular contents and structures than was the 6:3:1 solution. The air dried slides were later scraped with razor blades after soaking in distilled water to remove the diatoms from both sides. The diatoms removed from the exposed glass slides were prepared for specimen identification by cleaning in 30% hydrogen peroxide followed by oxidation of the cellular contents with the addition of small amounts of potassium dichromate (Van der Werff, 1955). The cleaned diatoms were rinsed with distilled water and settled in graduated cylinders. The final volume of concentrate containing the cleaned diatom frustules was measured and 1 ml subsamples were pipetted onto 22 mm square coverslips and air dried, until an adequate counting density was achieved. Two subsamples were taken from the cleaned diatoms removed from both sides of each slide, from pool or riffle habitats from each sampling period. The coverslips were permanently mounted on glass slides using Hyrax medium.

The slides preserved separately in glutaraldehyde were examined to determine proportions of non diatom algae present and the number of empty or dead diatom cells. Selected preserved slides were also examined with a scanning electron microscope to determine development and morphology of individual diatom colonies.

Counting was done at $1250 \times$ magnification on a Zeiss microscope equipped with phase contrast illumination and an oil immersion $100 \times$ Neofluar phase objective with numerical aperture of 1.30. Transects were taken moving across the coverslip

until between 250–450 valves were counted from each of the two slides for all sample dates (128 samples). Estimates of diatom densities were made from quantitative samples via the equation:

$$\text{cell} \cdot \text{m}^{-2} = \frac{(\text{Valves Counted}) (\text{Coverslip area } \text{mm}^{-2})}{(\text{Volume of Concentrate ml})} \cdot \frac{2[(\text{area counted } \text{mm}^{-2}) (\text{Subsample volume ml}) (\text{Area substrate sampled } \text{m}^{-2})]}{1}$$

Diatom species were recorded from the 500–900 frustules counted for each sampling date to determine species richness, diversity using the Shannon-Wiener formula (Southwood, 1978), species evenness, and species abundance. The use of short counts to determine species diversities (H') was adequate to determine general colonization patterns, and preferable to determination of species richness alone, since a species diversity measure like the Shannon function is more responsive to changes in species evenness when species richness is as high as it is in diatom communities (Stevenson, 1984).

Chemical analyses (N, P, Si, etc.) were conducted using auto-analyzer techniques recommended by the U.S. Environmental Protection Agency (U.S. EPA 1979), or by procedures listed in *Standard Methods* (American Public Health Association, 1980).

Description of the study area

The Ford River was a fourth order stream at the site sampled in the upper peninsula. The stream was 10–12 m wide under low flow conditions with depths ranging from less than 10 cm in riffle areas to more than 100 cm in deeper pools. The substrate of the riffles ranged in size from fine sand to large cobble but most sediments were in the gravel-pebble-small cobble range. The pools also contained some cobble but the predominant sediment category was fine sand (see Hynes 1970, p. 24 for sediment categories). Riparian vegetation was dominated by speckled tag alder (*Alnus rugosa* (Du Roy) Spreng), balm of gilead (*Populus gileadensis* Rouleau) and red-osier dogwood (*Cornus stolonifera* Michx.). Slide racks were placed in pool and riffle areas with maximum solar exposure and

minimum shading and were unshaded for most of the day. Discharge for the Ford River during summer low flows varied from 0.42–0.57 $\text{m}^3 \cdot \text{sec}^{-1}$ with discharges of up to 7 $\text{m}^3 \cdot \text{sec}^{-1}$ recorded during the autumn. Historical flows as high as 14 $\text{m}^3 \cdot \text{sec}^{-1}$ have been recorded during spring snow melt periods.

Results and discussion

Diatom density

Colonization dynamics are changed positively by the additive factors of cell reproduction and cell immigration, while negative effects may include cell loss through sloughing or death, and cell removal by grazers. Cell death, estimated from examination of the glutaraldehyde preserved slides, indicated approximately 2% of the diatom cells examined at any time were without chloroplasts. Cell death thus appeared not to be a major factor compared to the potential losses by sloughing. Grazers were also virtually absent from the slides and thus, were assumed to have little impact on colonization dynamics. Estimation of daily immigration and cell reproduction rates were calculated from comparisons of cell density levels of diatoms accumulated on glass slides over two consecutive sampling periods (Stevenson, 1984).

The density of diatoms on glass slides increased rapidly from day 2 through day 10 for set 1 for both pool and riffle habitats (Fig. 1, Table 1). A similar rapid increase occurred through day 14 for sets 2 and 3 (Fig. 1, Table 1). After day 10 or 14 for all three sets, the rate of increase slowed with the colonization curves reaching an apparent plateau by day 21 (for sets 1 and 2) or by day 28 (set 3) (Fig. 1). Even after this apparent plateau, small density increases continued through the end of the exposure period for each set (Table 1).

The lowest density recorded from pool samples occurred on September 4 after a 4 day exposure ($1.12 \times 10^7 \text{ cells} \cdot \text{m}^{-2}$) and the greatest density was recorded on October 26 ($3.74 \times 10^9 \text{ cells} \cdot \text{m}^{-2}$) after a 56 day exposure (set 3) (Fig. 1). In the riffle habitat, density was lowest after 2 days exposure in August for set 1 ($3.98 \times 10^6 \text{ cells} \cdot \text{m}^{-2}$) (Fig. 1), and greatest in set 3 on October 26 after 56 days exposure ($3.27 \times 10^9 \text{ cell} \cdot \text{m}^{-2}$) (Fig. 1). A t-test and

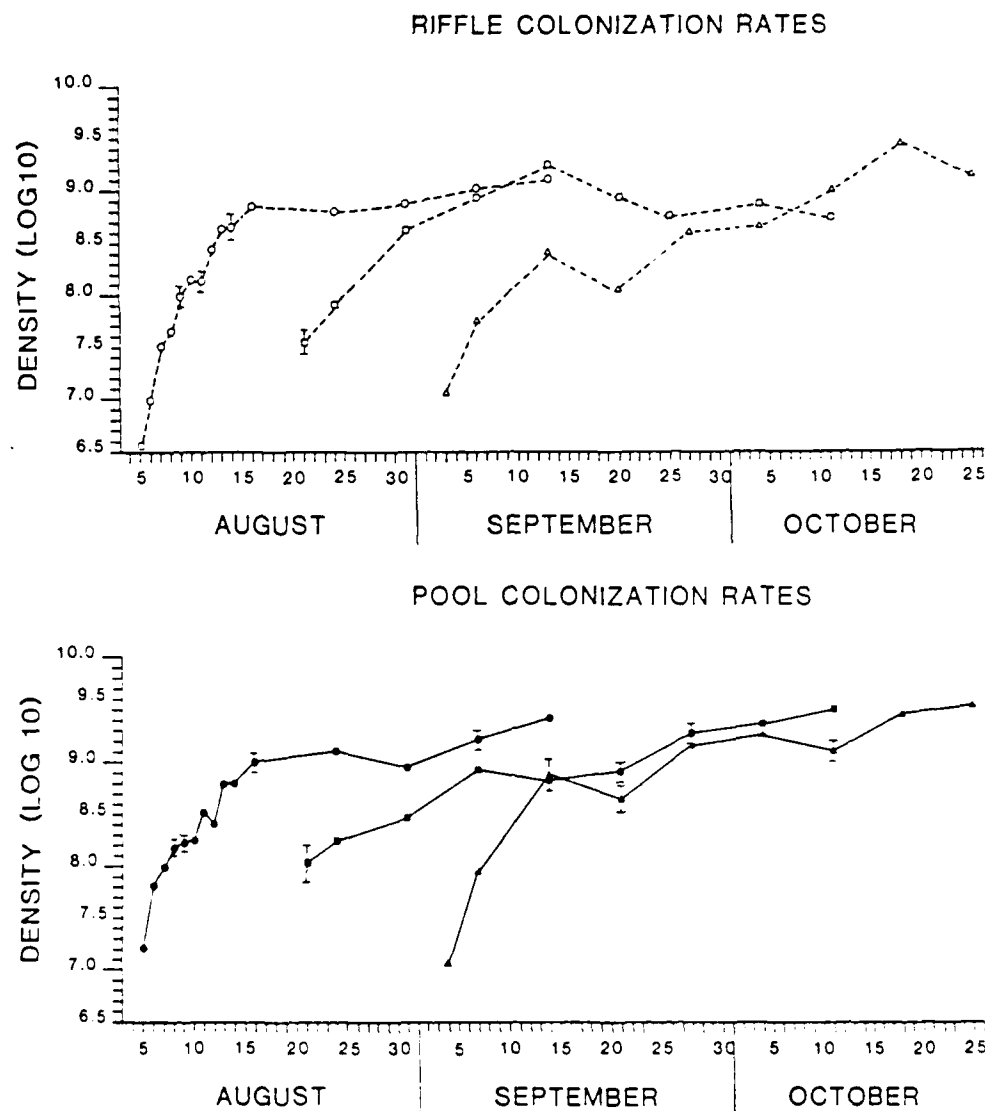


Fig. 1. Mean diatom cell densities (number $\cdot m^{-2} \pm S.E.$, $n = 2$) measured from glass microscope slides exposed in riffle and pool habitats. (---○--- set 1, ---□--- set 2, ---△--- set 3).

analysis of variance on the riffle and pool mean densities showed no significant differences between the mean density of diatoms in the riffle and pool.

The daily increases in cell density for set 1 (August 5 – September 14) dropped dramatically after day 17 in both riffle and pool habitats. The daily rate of 114.6% increase in total cell density observed for the riffle slides between 4 and 7 day exposures was considerably greater than the 16.9% calculated for the pool slides (Table 2). This higher

daily rate of increase appeared to be a function of the higher rate of cell immigration in the pool during the first 4 days (2.94×10^7 cells/day) as compared to the riffle (8.21×10^6 cells/day). More than 3.6 times the number of cells settled in the pool in these first 4 days than in the riffle, providing a greater initial 'seeding' of diatoms. Even though initial 'seeding' rates were slower in the riffle zone, perhaps because of greater current velocity, density differences rapidly disappeared between

Table 1. Log of Diatom Densities (Number cells·m⁻²) for Pool and Riffle Samples From Three Overlapping Exposure Periods 8-5-82 to 9-14-82 (Set 1), 8-21-82 to 10-12-82 (Set 2) and 9-4-82 to 10-26-82 (Set 3) ($\bar{x} \pm S.E.$, $n=2$).

Date out	Days Exposure	Pool	Riffle
<i>Set 1</i>			
8- 5-82	2	7.7222 \pm 0.0481	6.5998 \pm 0.0102
8- 6-82	3	7.8347 \pm 0.0111	7.0995 \pm 0.0072
8- 7-82	4	8.0683 \pm 0.0373	7.5111 \pm 0.0574
8- 8-82	5	8.1842 \pm 0.0829	7.6593 \pm 0.0385
8- 9-82	6	8.2346 \pm 0.0891	8.0346 \pm 0.0963
8-10-82	7	8.2465 \pm 0.0452	8.1634 \pm 0.0125
8-11-82	8	8.5127 \pm 0.0107	8.1325 \pm 0.0833
8-12-82	9	8.4294 \pm 0.0233	8.4253 \pm 0.0110
8-13-82	10	8.8046 \pm 0.0210	8.6404 \pm 0.0395
8-14-82	11	8.8039 \pm 0.0293	8.6637 \pm 0.1334
8-16-82	17	9.0791 \pm 0.0819	8.8704 \pm 0.0004
8-24-82	21	9.1110 \pm 0.0035	8.8072 \pm 0.0636
8-31-82	28	8.9538 \pm 0.0386	8.8925 \pm 0.0290
9- 7-82	35	9.2211 \pm 0.0996	9.0191 \pm 0.0105
9-14-82	42	9.4311 \pm 0.0372	9.1169 \pm 0.0128
<i>Set 2</i>			
8-21-82	4	8.0322 \pm 0.1834	7.5245 \pm 0.1090
8-24-82	7	8.2594 \pm 0.0292	7.9012 \pm 0.0087
8-31-82	14	8.4810 \pm 0.0055	8.7355 \pm 0.0304
9- 7-82	21	8.9426 \pm 0.0557	8.9190 \pm 0.0214
9-14-82	28	8.8211 \pm 0.0089	9.2511 \pm 0.0571
9-21-82	35	8.9269 \pm 0.0867	8.9389 \pm 0.0329
9-28-82	42	9.2929 \pm 0.0858	8.7724 \pm 0.0099
10- 5-82	49	9.3911 \pm 0.0154	8.8836 \pm 0.0224
10-12-82	56	9.5293 \pm 0.0402	8.7217 \pm 0.0315
<i>Set 3</i>			
9- 4-82	4	7.0553 \pm 0.0078	7.0790 \pm 0.0292
9- 7-82	7	7.9487 \pm 0.0200	7.7443 \pm 0.0078
9-14-82	14	8.8982 \pm 0.1551	8.4151 \pm 0.0170
9-21-82	21	8.6420 \pm 0.1197	8.0960 \pm 0.0215
9-28-82	28	9.1823 \pm 0.0402	8.6047 \pm 0.0733
10- 5-82	35	9.2939 \pm 0.0401	8.6976 \pm 0.0519
10-12-82	42	9.1218 \pm 0.0901	9.0234 \pm 0.0164
10-19-82	49	9.4918 \pm 0.0375	9.4976 \pm 0.0167
10-26-82	56	9.5688 \pm 0.0036	9.1885 \pm 0.0269

day 4 and day 7 because of the dramatic cell increases (114%) on the riffle slides as compared to the pool slides (17%). Thus, pool and riffle slides showed comparable overall patterns of colonization after day 7 (set 1) (Fig. 1).

Higher initial cell densities for pool slides above riffle slides were also recorded for set 2 (Aug. 21 – Oct. 12, Table 2). Again lower initial densities in the riffle were overcome by greater rates of daily increases between 14 and 21 days (Table 2). After

21 days, the pool slides showed more gradual daily increases (3–12.2%) than riffle slides and even some daily losses between 21 and 27 days (–3.6% day). The riffle zone slides showed consistently higher (13%/day) periphyton growth until 28 days exposure (Table 2). Riffle slides took slightly longer than pool slides to reach equivalent cell densities. Once a sufficient number of diatoms had attached or grown on the riffle slide (usually by day 4), very rapid accumulation or growth followed, resulting in the large daily percentage increases in total cell density observed in set 1 and set 2 riffle communities (Fig. 1, Table 2).

The first net loss of periphyton cells on samples examined weekly occurred on riffle slides after 28 days exposure (set 2, Table 2), compared to the first negative values seen for pool slides by day 21. The cells losses recorded for the riffle slides between days 28 and 42 contrasted with no net loss in the pool zone. This difference probably reflected the increased likelihood of cell dislodgement by the shearing stress of faster water currents in the riffle habitat.

In contrast to sets 1 and 2, set 3 (Sept. 4 – Oct. 26) initial cell densities were similar for both riffle and pool slides through day 4 with similar large daily increases in cell density thereafter (Table 2). The changing environmental conditions with colder temperatures, and rising waters from autumnal rains, may have resulted in less distinction between pool and riffle habitat immigration rates. Increased current velocity in the pools may have removed the initial advantage of more cells settling on the slides, or increased currents may have made settling and possible cell attachment more equitable between pools and riffles. The high correlation coefficient between pool and riffle growth rates (Table 2) of 0.82 for set 3 in the fall compared with coefficients of 0.36 and 0.15 for set 1 and 2 indicated that little difference occurred in growth rates or cell accumulation rates between these two habitats in the fall, whereas distinct differences had occurred during the earlier two exposure periods.

A separate short term study comparing slides removed daily from riffles and pools (Aug. 3 – Aug. 14) showed much greater cell density increases in the riffle zone community through day eleven than in the pool community (Table 3). The initial 'seeding' level of immigrating diatom cells that occurred on slides from the pool habitat was more than 13

Table 2. Calculated daily rates of change in diatom density from comparison of weekly measurements of diatom density in riffle and pool habitats.

Days	Riffle		Pool	
	Change in Diatom Numbers ¹	Percent Change ²	Change in Diatom Numbers	Percent Change
<i>August 5 - September 14 (Set 1)</i>				
0 - 4	0.8209	-	2.9433	-
4 - 7	3.7631	114.6	1.9877	16.9
7 - 17	5.9621	40.9	9.1854	51.8
17 - 21	-2.1805	-2.9	2.7900	2.5
21 - 28	1.8237	2.8	-5.4971	-4.3
28 - 35	3.7546	4.8	13.0340	14.4
35 - 42	3.7729	3.6	12.7040	7.0
42 - 49	-	-	-	-
49 - 56	-	-	-	-
<i>August 21 - October 12 (Set 2)</i>				
0 - 4	0.8630	-	2.9360	-
4 - 7	1.5047	43.6	2.1567	18.4
7 - 14	5.0484	63.4	1.7224	9.5
14 - 21	5.6834	13.1	8.2941	27.4
21 - 28	13.8170	16.6	-3.1543	-3.6
28 - 35	-13.2430	-7.4	5.9414	9.0
35 - 42	-4.9033	-5.6	13.1860	12.2
42 - 49	3.3994	6.4	6.5829	3.3
49 - 56	-3.2949	-4.4	13.3610	5.4
<i>September 4 - October 26 (Set 3)</i>				
0 - 4	0.3005	-	0.2940	-
4 - 7	1.4496	120.6	1.1083	97.6
7 - 14	2.9246	52.7	10.7570	120.9
14 - 21	-1.9336	-7.4	-5.5240	-6.6
21 - 28	4.0477	32.4	15.3380	33.7
28 - 35	1.3380	3.3	6.3814	4.2
35 - 42	7.9174	15.8	-8.9043	-4.5
42 - 49	29.8670	28.3	25.1800	18.6
49 - 56	-22.8660	-7.3	8.4300	2.7

¹ Expressed as number of cells of $m^{-2} day^{-1} 10^7$.

² Percent change in total diatom cell density from comparison of current to previous diatom cell density.

times the level found after 2 days for the riffle slides (Table 3). Correlation coefficients calculated for riffle and pool periphyton daily growth rates indicated little similarity ($r = 0.17$). Regression analysis on the number of cells added or lost per day between riffle and pool showed little similarity in variability between the two habitats ($r^2 = 0.14$, $p > 0.25$). The net cell losses that appeared by day 8 for the riffle and by day 9 for the pool indicated that substantial periphyton cell loss occurred during early colonization stages before the periphyton community was well developed. Cell losses thus occurred earlier and were more frequent (Tables 2 and

3) than has generally been reported (Ball & Bahr, 1975; Burton & King, 1983). Failure to account for such algal loss during early colonization or inadequate measurements of algal losses from sloughing (Bott, 1983) may indeed help explain why researchers attribute such importance to allochthonous detrital standing crops (Minshall, 1978) in streams. Such losses may also influence the nature and course of early developing periphyton communities more significantly than the greater cell losses from mature, fully developed periphyton communities, by creating mosaic patterns including recently colonized areas of opportunistic algal species to-

Table 3. Measured daily accumulation rates of diatoms expressed as percent change of previous days cell density.

Days	Riffle		Pool	
	Change in Diatom Numbers ¹	Percent Change ²	Change in Diatom Numbers	Percent Change
0-2	0.1990	-	2.6535	-
2-3	0.8599	216.0	1.5293	28.9
3-4	2.0257	161.0	4.9368	72.2
4-5	1.2972	39.0	3.7890	32.2
5-6	6.5151	142.0	1.9650	12.6
6-7	3.4770	31.3	2.0900	1.2
7-8	-0.5340	-3.7	1.4830	83.6
8-9	12.5920	89.7	-5.6470	-17.3
9-10	17.2340	64.7	3.6921	137.2
10-11	10.4650	23.9	-0.3600	-0.1

¹ Expressed as number cells $\cdot m^{-2} \cdot day^{-1} \cdot 10^{-7}$.² Percent change in total cell density from previous days total cell density.

gether with more mature areas of later successional algal species, thus keeping diversity high (Hoagland, 1983).

Diversity changes

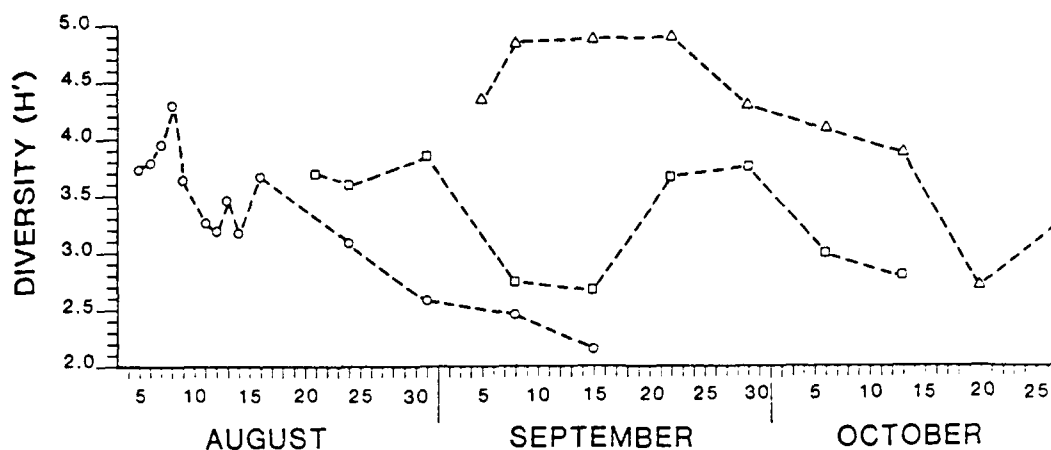
Mean species diversities did not differ significantly overall between riffle and pool habitats (t-test, $p > 0.5$). Gradual declines in diversity after early peaks occurred for both riffle and pool habitats (Fig. 2). Set 1 showed a maximum diversity value of 4.52 after 2 days exposure, set 2, 4.60 after 4 days, and set 3, 4.65 after 7 days. Maximum number of species in counts of 500 valves occurred within the first week of exposure for all three sets while minimum diversities were consistently recorded with increasing exposure times. Species diversity for pool habitats was negatively correlated with increasing exposure for sets 1, 2, and 3 with correlation coefficients of -0.61, -0.83, -0.71 respectively. Riffle species diversities were highest after 5 days exposure for set 1, 14 days for set 2 and 21 days for set 3. Maximum species diversity in the riffle was thus reached at a later exposure period for each successive experimental set. Although there were no overall differences, riffle species diversity declines lagged slightly behind the pool changes, perhaps reflecting differences in colonization rates as discussed above. There were some seasonal differences in species diversity (Fig. 2). Species diversities (H') decreased rapidly for set 1, then at reduced rates for set 2, and set 3 as fall ap-

proached (particularly noticeable for the riffle). Diversities after 56 days of exposure for set 2 and set 3 also remained higher when contrasted with set 1 (Fig. 2). The final slide set exposed during September and October was characterized by Shannon-Wiener diversity greater than 4.0 through day 35 in the riffle, while neither of the earlier two sets approached such high diversity values for long (only one value for either of the first two sets exceeded 4.0) (Fig. 2).

The colder water temperatures and increased current velocities measured from mid-September through October apparently maintained riffle periphyton in an earlier development stage with less dominance by individual species and higher overall diversity. There were no significant differences ($p > 0.1$) between riffle and pool diversities for set 1. Species diversity was, however, significantly greater in pool habitats than in riffle habitats for set 2 ($p < 0.05$), while significantly higher diversity values were calculated for riffle habitats than the pool habitats in the fall for set 3 ($p < 0.01$).

The high initial diversities for each of the three overlapping experiments (Fig. 2) indicated that the diversity decreases did not occur as a result of any drop in available species numbers in the theoretical species pool. The apparent decreases in species diversity must, therefore, be a measure of increased dominance by a few select species. The species evenness index (Fig. 3) supported this contention with decreases in evenness occurring in parallel with decreases in species diversity over time.

FORD RIVER: RIFFLE SPECIES DIVERSITIES



FORD RIVER: POOL SPECIES DIVERSITIES

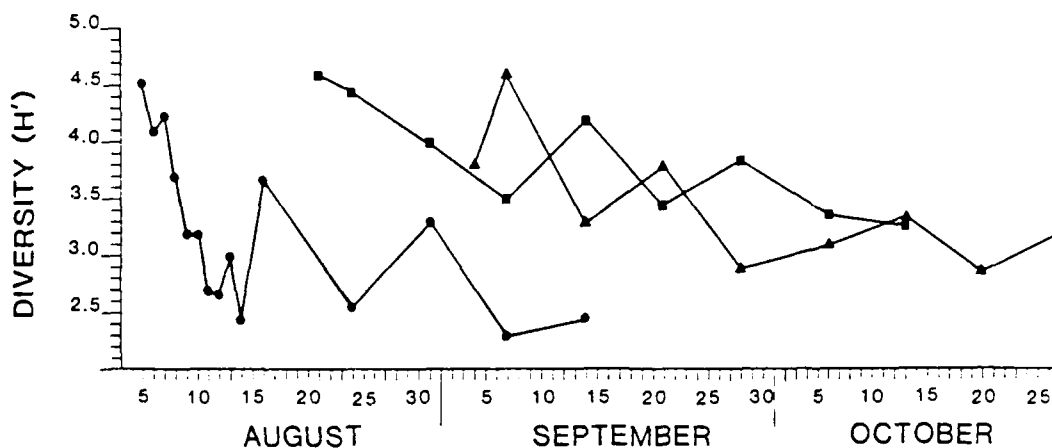


Fig. 2. Diatom species diversities (H') determined from glass slides exposed in riffle and pool habitats for three overlapping exposures. (—○— set 1, —□— set 2, —△— set 3).

Statistical comparisons between the evenness index for riffle and pool habitats (Table 4) suggested that the pool habitats were more equitable in terms of distribution of individuals among species than were the riffle habitats for the first two colonization periods (Aug. 1 – Oct. 12). These data and the diversity data (Table 4), indicated that perhaps cell attachment and/or cell reproduction were less competitively governed in the pool habitat. The rever-

sals of both diversity and evenness indices for set 3, exposed from September 4th through October 26th, with riffle slides showing greater diversity and evenness indicated that some seasonal factors had changed the periphyton community composition of riffle and pool habitats. There were no changes in nutrient chemistry over the time of this study (Table 5). Thus, temperature and hydrologic changes appear to have influenced

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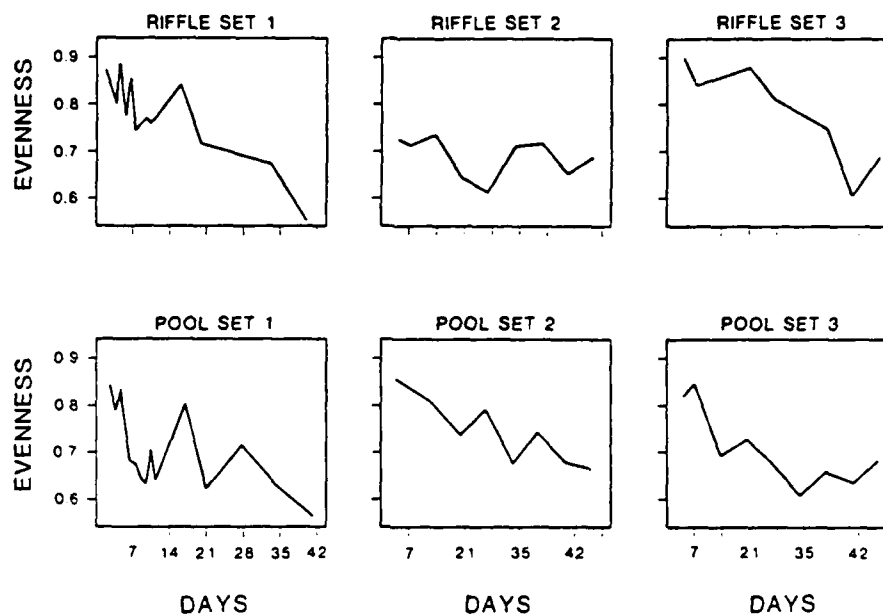


Fig. 3. Diatom species evenness values from riffle and pool slides for three overlapping exposures: 8-5-82 to 9-14-82 (set 1), 8-21-82 to 10-12-82 (set 2), and 9-4-82 to 10-26-82 (set 3).

tant variables. Water temperature changed from 14.5°C on August 23, to 3.5°C on October 22nd. Water levels increased from the fall rains with corresponding current velocity increases. Thus, temperature decreases, increased current velocity, and decreased light all could have influenced the diatom communities.

Dominance and species succession

Over 300 diatom taxa were identified from the three overlapping colonization periods. In all three series, the dominance by specific diatom species changed over time. Major species were well established after 10–11 days exposure for the pool habitat for set 1 and after 21 days exposure for the riffle habitat (Fig. 4). *Cymbella minuta* var. *silesiaca* (Bleisch ex Rabh.) Patr. and *Amphora* spp. showed an early dominance prior to day 4 in both pool and riffle areas. Between day 4 and 13, dominance switched to *Fragilaria vaucheriae* (Kutz.) Peters and *Synedra ulna* (Nitz.) Ehr. in riffles where they accounted for 40–50% of the diatoms encountered. However, these two species accounted for less than 15% of the diatoms encountered during the same period in the pool area. The high proportions of

Fragilaria vaucheriae and *Synedra ulna* observed in the early exposures (Fig. 4) appear to indicate a facility for immigration and attachment by these two species onto relatively clean substrate surfaces. Calculated daily doubling rates of above 2.0 (formula from Stevenson, 1984) for the riffle study indicated that indeed the immigration rates were enhanced for *F. vaucheriae* and *S. ulna* above those for *Cocconeis placentula* var. *euglypta* (daily doubling rate of 1.3) and *Cymbella minuta* var. *silesiaca* (1.75). Similarly high combined relative abundances (35.2%) for *Fragilaria vaucheriae* and *Synedra ulna* were also observed by Stevenson (1983) after 24 hours exposure of unaltered ceramic floor tiles in Fleming Creek; a smaller order stream located in Southern Michigan.

Table 4. Results of t-tests on paired comparisons between species diversity and species evenness for pool and riffle slides.

Experimental Series	Diversity	Evenness
Set 1 August 5 – September 14	Pool = Riffle (N.S., $P > 0.10$)	Pool > Riffle (**, $p < 0.01$)
Set 2 August 21 – October 12	Pool > Riffle (*, $p < 0.05$)	Pool > Riffle (*, $p < 0.05$)
Set 3 September 4 – October 26	Pool < Riffle (**, $p < 0.01$)	Pool < Riffle (*, $p < 0.05$)

Table 5. Chemistry of Ford River 1982. Values are Means \pm One Standard Deviation; N is Indicated in Parentheses.

	AUG	SEP	OCT	NOV
Nitrate-N	(17)	(16)	(7)	
mg N l ⁻¹	0.025 \pm 0.014	0.033 \pm 0.028	0.030 \pm 0.017	0.068
Nitrite-N	(17)	(16)	(7)	
mg N l ⁻¹	0.013 \pm 0.003	0.013 \pm 0.051	0.022 \pm 0.025	0.017
Ammonium-N	(16)	(16)	(7)	
mg N l ⁻¹	0.024 \pm 0.025	0.056 \pm 0.051	0.043 \pm 0.025	0.060
Kjeldahl				
Nitrogen	(14)	(23)	(7)	
mg N l ⁻¹	0.020 \pm 0.008	0.030 \pm 0.015	0.041 \pm 0.033	0.031
Total				
Phosphorus	(13)	(15)	(3)	
mg P l ⁻¹	0.41 \pm 0.09	0.60 \pm 0.18	0.66 \pm 0.09	-
Silica	(17)	(16)	(7)	
mg S l ⁻¹	8.53 \pm 1.03	8.13 \pm 0.95	8.27 \pm 0.17	9.60
Chloride	(17)	(16)	(7)	
mg Cl l ⁻¹	3.40 \pm 0.79	4.28 \pm 0.68	4.36 \pm 1.05	2.50

* Soluble reactive phosphorus was always below 0.005 mg P l⁻¹.

The continued persistent rise in dominance by *Cocconeis placentula* var. *euglypta* (Ehr.) Cl. in both habitats (Fig. 4) can be partially explained by the existence of sustained high daily doubling rates while *F. vaucheriae*, *S. ulna*, and *C. minuta* var. *silesiaca* showed dramatic declines in growth rates with increasing exposure. *Cocconeis* spp. (predominantly *C. placentula* var. *euglypta* and *C. placentula* var. *lineata* (Ehr.) V.H.) dominated the pool community (50% by day 7), while in the riffle samples (Fig. 4) these same species became dominant (22%) only after a 17 day exposure. From day 21 until day 42 the riffle and pool diatom communities appeared to show nearly identical dominance patterns, with increases by *Cocconeis* spp. and decreases in levels of *Fragilaria* and *Synedra* spp. as well as declines in *Cymbella* and *Amphora* spp. (Fig. 4).

The observed early differences in major diatom species between the two habitats before day 21 thus disappeared with increasing duration of exposure. This similarity after 21 days indicated that most species were well established regardless of habitat by day 21 in the Ford river and that sampling between days 21 and 42 would most likely approximate the 'mature' communities in which species dominance had been previously well established.

Changes in successional patterns during colonization are apparent for the three colonization periods. There is a general decrease in domi-

nance by *Cocconeis* spp. from set 1 through set 3 (Fig. 5). *Cocconeis* spp. accounted for 80% of the population by day 42 for set 1, 45% for set 2, and 35% for set 3 (Fig. 5). This decrease in dominance by *Cocconeis* spp. in both riffles and pools from the first successional period (Aug. 5 - Sept. 14) to later ones was accompanied by an increase in dominance of several other species as fall approached particularly in the riffle habitats (Fig. 5) with *Achnanthes* spp. and *Gomphonema* spp. becoming more important as temperatures cooled and water level increased. The genus *Gomphonema* increased from less than 5% of the total community in set 1 to between 20-30% in set 3 (Fig. 5). *Gomphonema angustatum* var. *productum* Grun. was the most often encountered species. Colonies of *G. angustatum* var. *productum* observed with the scanning electron microscope showed a highly arbuscular form with the branches elevating individual cells above the bottom substrate surface which was often completely covered in a cobblestone fashion with the tightly adherent cells of the genus *Cocconeis*. Individuals of *Gomphonema*, which were rarely encountered in set 1, were found commonly or abundantly in sets 2 and 3 (Fig. 5). This temporal ascendancy indicates the importance of other parameters besides water current which must have influenced immigration or growth rates of these stalked diatoms. The low abundance levels observed in set 1 for members of this genus in both riffle and pool

FORD RIVER COLONIZATION STUDY
SPECIES DOMINANCE SET 1

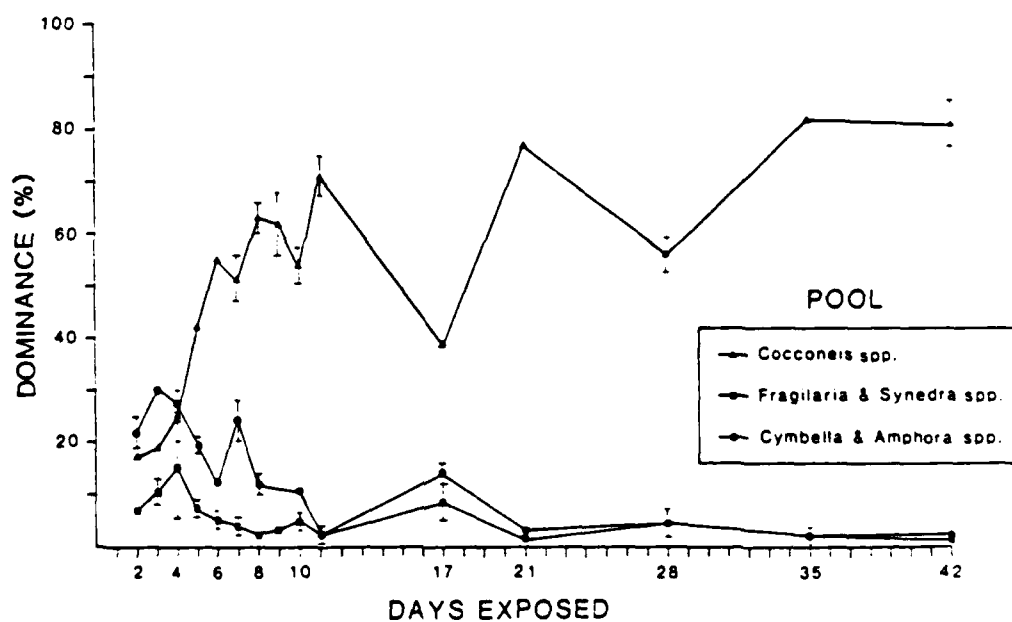
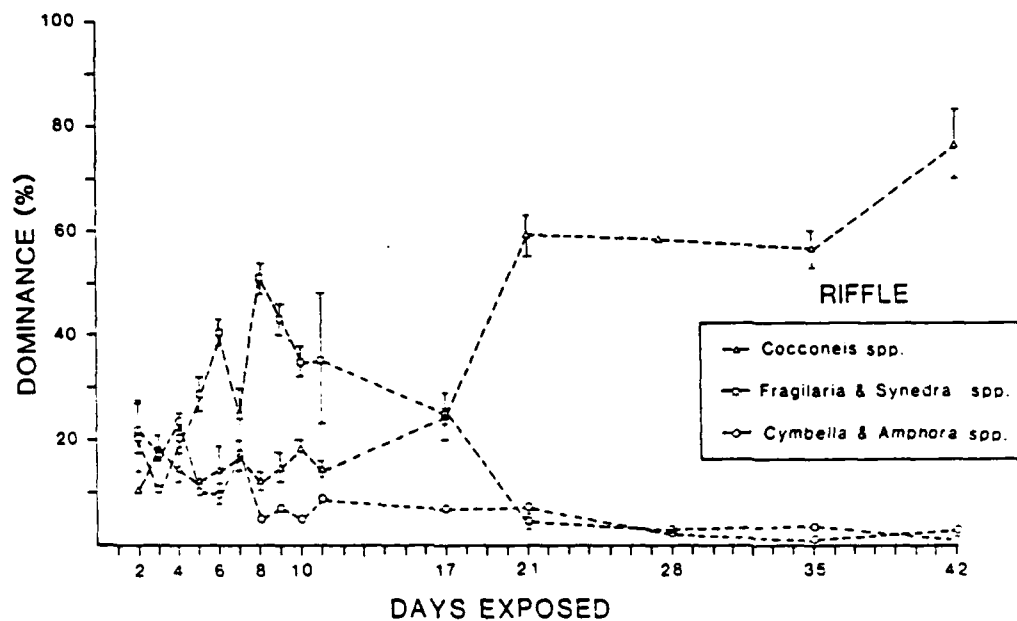


Fig. 4. Percent dominance ($\bar{x} \pm S.E.$, $N = 2$) by the common diatom species occurring on glass slides exposed from 8-5-82 to 9-14-82 in a riffle and pool habitat.

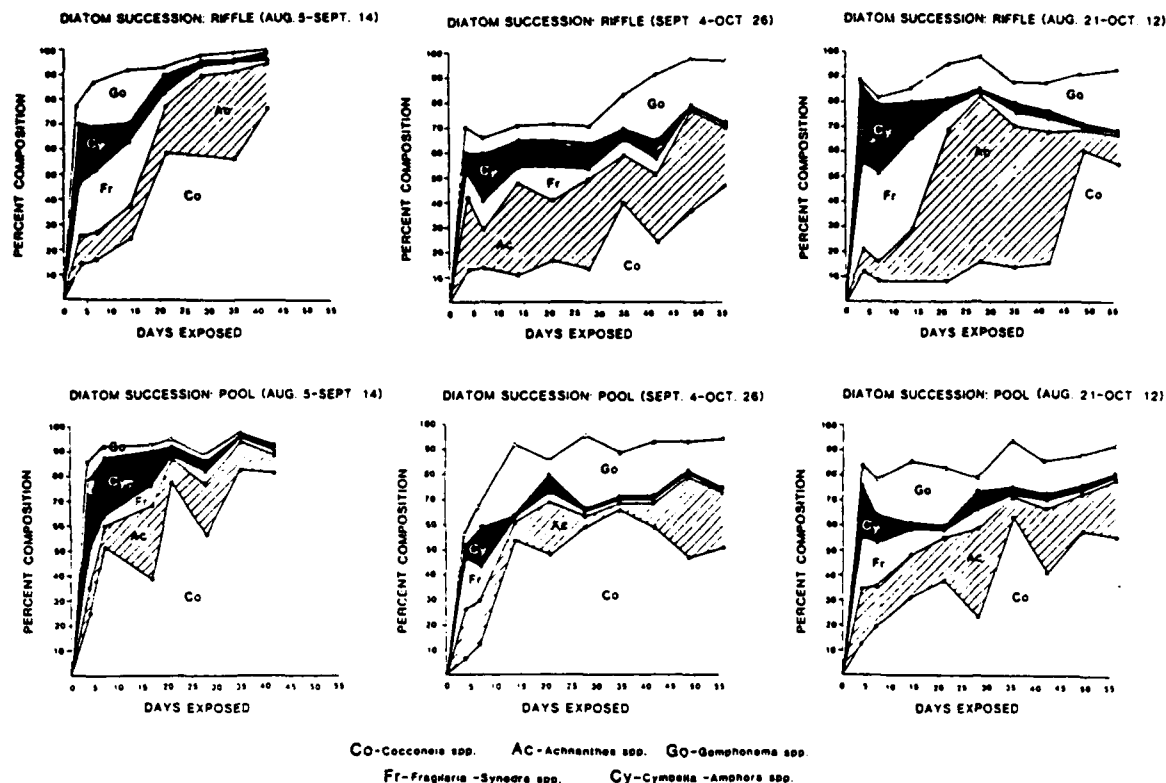


Fig. 5. Cumulative percent composition of the diatom community by dominant species groups occurring on glass slides in riffle and pool habitats from three overlapping exposures.

habitats indicates that current flow differences at that time were not determining factors.

The increased abundances of the stalked diatoms in set 2 and set 3 may partially explain the observed decreases in dominance by *Cocconeis* spp. in the riffle, particularly if these large, more erect, colonies restricted light penetration to the substrate or restricted nutrient uptake by interrupting the current below to the underlying cells (Whitford, 1960). The observed increases for *Gomphonema* species were similar to recorded increases by this group in other rivers during cold water conditions (Butcher, 1932; Blum, 1956).

The decrease in dominance during the fall by the reportedly superior competitors, *Cocconeis* spp. (Dickman & Gohnauer, 1978; Marcus, 1980), is correlated with water flow increases, water temperature drops, light level changes, and other seasonal variables which may keep potentially superior competitors such as *Cocconeis* from outcompeting all other species (= overgrowing of Dickman & Gohn-

nauer, 1978). Seasonal changes may thus act the same way as the spring floods that serve to reset the algal community to early successional stages. Seasonal changes may decrease the abundance of previously combined dominant species of a genus and perhaps alter the morphology of the attached diatom community by enhancing the growth of stalked, erect diatom colonies over the growth of small closely appressed unicells. Such seasonal fluctuations in temperature, light, and current may thereby keep both diversity and species equitability high, by providing a wider range of environmental conditions, affording little likelihood that a single species can maintain a position as a superior competitor throughout the year.

Conclusion

Species diversity peaked quickly during colonization studies, along with species evenness. Both indi-

ces decreased in value as the length of exposure increased and dominance became established. Early colonizing diatom species (fast immigrants) that occasionally accounted for large proportions of the total diatom community were soon replaced by other diatom species (fast reproducers) that tended to persist through time. In all samples examined for this study the major dominant species were well established by day 28. Slight changes in species dominance occurred throughout time, along with continued gradual increases in cell density. Severe net cell loss (up to 17% of total) was recorded after only a 9 day exposure. Rapid growth rates (accumulation rates) characterized the riffle habitat. A larger initial seeding level of cells characterized the pool habitat. In both pool and riffle habitats cell densities were similar after 6–8 week exposures. Seasonal changes appear to strongly influence diatom species succession. Seasonal changes in water current, temperature or light may act in similar fashion to more dramatic storm or flood events to reset periphyton to early successional stages, resulting in increased diversity and species evenness. Thus, small, often unnoticed seasonal changes, while appearing less dramatic, may have as profound an effect (although more gradual) on the stream periphyton community as the scouring from floods each spring. It is thus possible that the stream diatom community in many instances 'resets' with each seasonal change, as previously dominant species are replaced by new species or species groups. Each 'reset' may possibly serve to minimize or reduce the continued dominance by any single species in the periphyton.

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Element 3- Effects of Insect Grazer populations on Periphyton communities

Changes from workplan - None.

Rationale

Small E.L.F. effects on the aquatic system may be unnoticable on impact only very small, microscopic single celled algae species. If these same algae are important food sources for selectively feeding stream grazers, severe impacts on the trophic linkages within the system could result. Restructuring of the species composition of the autotrophic community, leading to dominance by non-selected, non-palatable, or non-digestible algal species might be one such consequence. This could result in reduced growth, or lower overall production of benthic grazers. Thus, an essential invertebrate food source of predatory fish species might be significantly reduced.

Additionally the potential may exist for E.L.F. to cause behavioral changes in the grazers themselves. This might result in changes in feeding activity by increasing or decreasing feeding rates or otherwise changing "typical" grazer feeding behavior.

Little is currently known about interactions between stream herbivores (grazers) and the attached algal community in freshwater systems. Most research on freshwater herbivore-algal interactions has been conducted in either ponds (Kesler 1981, Hunter 1980) or in laboratory streams (Kende and Wilhm 1972, Sumner and McIntire 1982). Many of these studies have only documented grazer induced changes in periphyton standing crop, either by extracting chlorophyll a or by also measuring accumulations of organic matter as ash free dry weight (AFDW). These measures provide only gross approximations of herbivore effects on the total periphyton community. These techniques provide little or no information on the dynamics of the algal species interactions in the presence or absence of herbivores. Ecological studies on the species responses of the algal community to aquatic herbivory have been largely ignored. Only a few studies have attempted to evaluate the effects of herbivores by examining other algal responses besides chlorophyll a or biomass in the algal community. These include the studies of Lamberti and Resh (1983) on the impact of grazing by Helicopsyche larvae. They measured algal turnover rates as well as chlorophyll a levels and noted that grazing resulted in an attached algal community consisting predominantly of a diatom monolayer. When Helicopsyche were excluded, the algal community changed from a diatom film to a thick growth of filamentous green algae. Eichenberger and Schlatter (1978) found that grazing by chironomids in stream channel maintained a mixture of filamentous green algae and diatoms. Exclusion of chironomid grazers from a second channel resulted in succession proceeding from filamentous green algae to blue-green algae. These studies have demonstrated that grazers can alter the succession of algal species on substrates. Dickman and Gochmauer (1978) indicated that grazer pressure in a stream prevented members of the algal genus Cocconeis from out-competing other algal species. This reduced competition may have increased the establishment of other algae and led to overall greater algal species diversity on the grazed substrates. To our knowledge no detailed study of the effects of grazing on periphytic algal species occurrence and abundance in lotic

systems has been conducted.

Several studies have documented the effects of algal distribution on intra- and inter-specific competition among grazers (Hart 1983, McAuliffe 1983, 1984, Wiley and Kohler 1984), and Hart (1985) performed preliminary observations on a sample of five guts from the sessile trichopteran, Leucotrichia, for algal species determinations. These studies indicated that periphyton abundance and patchiness are important determinants of grazer distribution and abundance. These studies have not, however, examined the precise species composition of the algal food resources in detail, nor have they examined the effects of a mobile grazer on the attached algal community. Our hypothesis is that grazer abundance is an important determinant in structuring the attached algal community, and that the consequences of grazing can dramatically alter the species abundances in the periphyton.

Larvae of Glossosoma nigrior are known to be specialized grazers (Cummins 1973, Oemke 1983). Recent investigations of in situ food selections by various instars of the larvae (Oemke 1984) indicated that small, unicellular algal forms were more often ingested than were large, stalked or filamentous types of diatoms. Those diatom species which were preferentially ingested by grazing larvae may show significant differences between gut contents abundances and abundances in the surrounding periphyton (Oemke 1983). Thus, we hypothesized that grazing by Glossosoma would lead to reduced abundance of small growth forms of preferentially selected diatom species, like Cocconeis placentula vars. (Oemke 1984), which are known to dominate the flora during the summer months (Oemke and Burton 1986) and to a concomittant increase in abundance of other non selected species or growth forms in the periphyton.

Objective

This element will examine the behavior of typical grazing invertebrates to provide the data necessary for linking invertebrate herbivores to the periphyton community based on trophic level analyses. This objective includes the determination of the effects of various levels of herbivory on periphyton community dynamics.

Materials and Methods

In 1985, we designed and built small microcosm streamside flow-through artificial streams for monitoring effects of grazers on periphyton. These plexiglass streams were constructed from 1.27 cm plexiglass and were 1 m long with three 15 cm wide channels fed from a common reservoir. This reservoir was filled by pumping water from the Ford river through a 300 micron mesh filter into the reservoir. The reservoir also contained polyester fibers as an additional filter to remove suspended sediments. This double filter system proved necessary because of excessive settling of suspended particles on substrates in its absence. The pumps were powered by a heavy duty marine battery which had to be exchanged and recharged daily. Two of these streams were constructed so that identical studies could be conducted at FEX and FCD simultaneously. However, the 1985 studies were conducted at one site per

run as means of developing the technique. In 1986, the simultaneous experiments were conducted and preliminary results will be reported below.

Ceramic tiles (3.6 cm^2) were placed in the river 25-30 days prior to experiment initiation for periphyton colonization. After this colonization period, the tiles were placed in the 4 chambers in each channel. Each chamber was separated from the next chamber by a plastic screen with mesh small enough to prevent exchange of grazers between chambers. These 12 chambers (4 x 3 channels) allowed introduction of different numbers of grazers (3 levels) in a block design with up to 4 replications per treatment. Tiles were taken at random from each chamber at the end of each experiment for determination of chlorophyll *a* ($n=8$ per chamber), organic matter biomass ($n=8$), and cell counts ($n=4$).

In 1985, we were able to conduct three preliminary experiments. In the first experiment, the tiles were all covered with sediment on the river bottom at the end of the colonization period. Thus, we conducted colonization experiments with uncolonized tiles in the plexiglass streams. Also, the grazer, *Glossosoma nigrior*, was unavailable in sufficient quantities at the time of this experiment. Thus, it was conducted with *Pycnopsyche* at densities of 0, 5, and 15 per chamber primarily as a test of techniques. The second two successful runs were conducted with *Glossosoma nigrior* (Trichoptera: Glossosomatidae) at densities of 0, 15, and 30 larvae per chamber. The *Pycnopsyche* experiment proved to be of little use for these types of studies and has not been analyzed in detail. Since only preliminary data were available for the 1985 *Glossosoma* experiment for the last annual report, the 1985 results will be summarized in some detail in this report. Also, preliminary data from the 1986 paired tests will be discussed.

Results and Discussion

A. The 1985 Study

Enumeration of diatom species present and determinations of relative abundances of the major species (Table 3.1) revealed significant shifts in species dominance as a consequence of *Glossosoma* grazing. *Achnanthes affinis* Grun. var. *affinis*, a small pennate diatom, showed highly significant ($P<.01$) increases in relative abundance on grazed over ungrazed tiles (Table 3.1). *A. affinis* increased in relative abundance from 13% on control tiles to 34.7% and to 28.8% under grazer densities of 15 and 30 larvae per chamber. Cell concentrations of *A. affinis* also increased significantly ($P<.05$) on tiles subjected to *Glossosoma* grazing when compared to ungrazed tiles.

The fall experiment corroborated the earlier summer experimental results with significant ($P<.05$) increases in *Achnanthes affinis* occurring on grazed tiles over ungrazed tiles in terms of both relative abundance and actual cell concentrations (Table 3.1).

The dominant diatom species on ungrazed tiles in the summer was *Cocconeis placentula* v. *lineata* (44% relative abundance). It declined in relative abundance to 31% as grazer density increased to 15 per chamber

Table 3.1 Percent relative abundances of two diatom species in larval gut contents and in periphyton exposed to different grazer densities ($\bar{X} \pm \text{S.E.}, n$).

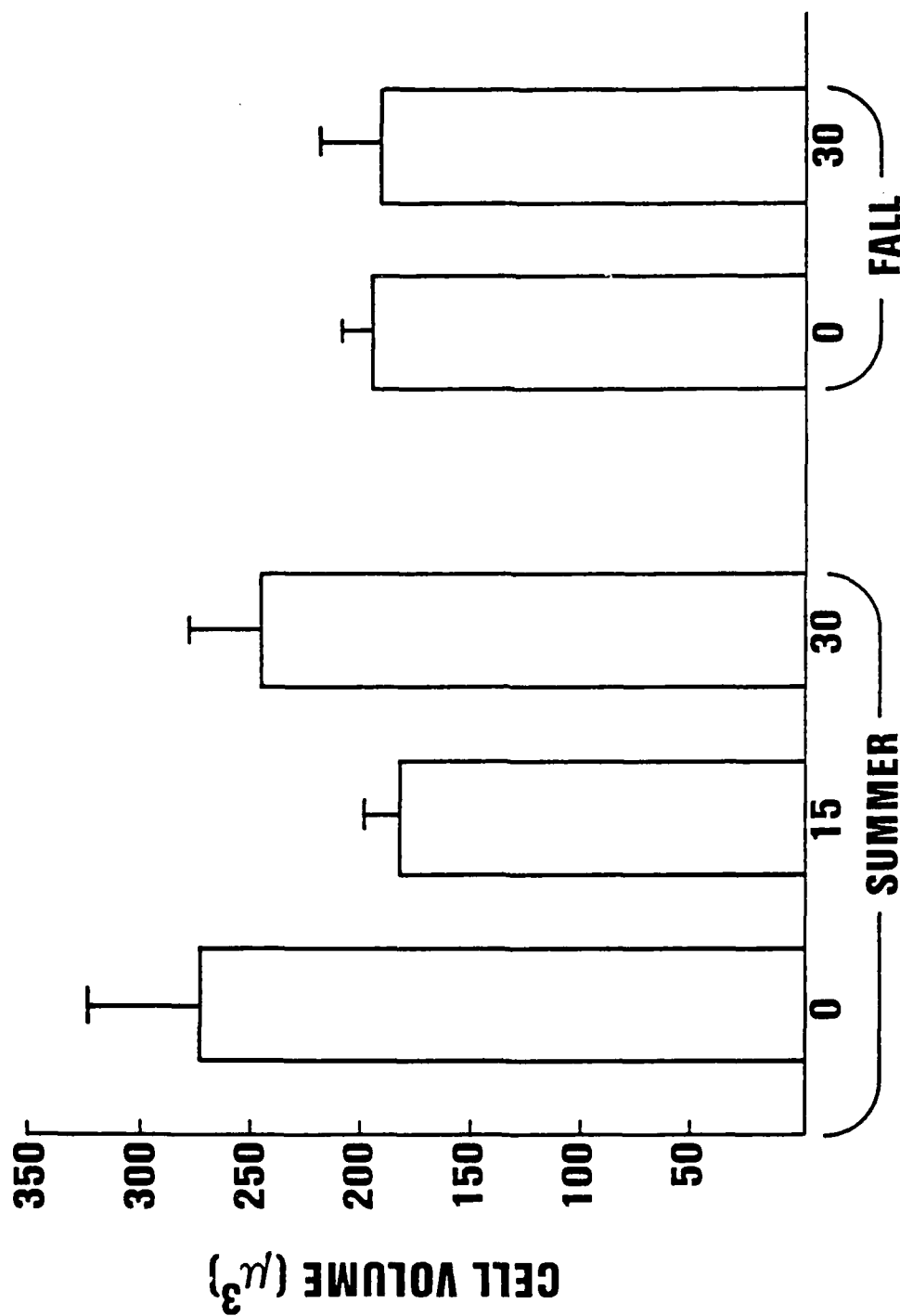
SOURCE EXAMINED	GRAZER DENSITY	<i>C. placentula</i> var. <i>lineata</i>	<i>A. affinis</i>
Summer (7-31-85 to 8-5-85)			
Gut Contents	15	46.3 ± 7.6 (3)	30.0 ± 5.0 (3)
Grazed Tile	15	31.0 ± 6.1 (6)	34.7 ± 5.0 (6)
Ungrazed Tile	---	43.8 ± 4.8 (6)	12.7 ± 1.8 (6)
Gut Contents	30	12.7 ± 6.7 (3)	39.3 ± 2.3 (3)
Grazed Tile	30	24.0 ± 7.9 (6)	28.8 ± 5.1 (6)
Ungrazed Tile	---	43.8 ± 4.8 (6)	12.7 ± 1.7 (6)
Fall (9-10-85 to 9-18-85)			
Gut Contents	30	4.0 ± 1.5 (3)	59.0 ± 10.5 (3)
Grazed Tile	30	9.0 ± 3.3 (4)	61.0 ± 5.4 (4)
Ungrazed Tile	---	10.5 ± 2.4 (4)	39.8 ± 3.4 (4)

and to 24% with 30 per chamber, although these declines were statistically significant ($P < .25$). Thus, Glossosoma grazing appears to lead to increased dominance by Achnanthes at the expense of Cocconeis. The mechanism for this shift could involve selective feeding by Glossosoma, perhaps on a size selective basis. Thus, cell size was calculated. The average size or volume of diatom cells remaining on grazed tiles was smaller than the average cell size in the ungrazed periphyton (Fig. 3.1). However, these size differences were not significantly different in the summer experiment. There were no significant size differences for the fall experiment either. Thus, food selection on the basis of size does not appear to be occurring. Examination of gut contents and fecal material after gut passage suggests that Cocconeis is usually digested during gut passage while many Achnanthes are not. Thus, differential survival rates during gut passage may lead to the increased dominance of achnanthes on the grazed tiles.

Species diversity was decrease by grazing ($P < 0.05$) in the September experiment (Table 3.1). This result suggested a comparison of diversity of flora in Glossosoma guts compared to grazed and ungrazed tiles. Species diversity of the gut flora from the September experiment was equal to diversities from grazed tiles but significantly lower ($P < 0.05$) than species diversities determined from the ungrazed, control tiles. Evenness values from gut studies were also significantly lower ($P < 0.05$) than values from ungrazed tiles. The September experiment results indicated that grazing significantly decreased both species diversity and species evenness values below ungrazed levels (Table 3.2). This data suggested that grazing by Glossosoma altered the species composition of the periphyton by reducing the total number of species present as well as altering the distributions of remaining species. In the summer experiment, the species diversity and species evenness indices determined for ungrazed periphyton were not significantly different from diversity or evenness calculated on tiles grazed by 30, or 15 larvae.

Gut diversities generally reflected the diversity of the diatom community remaining in the grazed periphyton community for both larval density groups in the summer; at a larval density of 15 individuals, grazed tile diversity was 2.8 versus a gut diversity of 2.4 and at larval density of 30 individuals, grazed tile diversity was 3.2 versus a gut diversity of 3.5. Results of t-tests comparing mean species diversities calculated from gut analyses to species diversities from ungrazed, control tiles indicated that at the lower density of 15 larvae per chamber in the summer, gut evenness values were significantly below the species evenness values recorded on ungrazed tiles ($P < 0.05$). These results were similar to the significant differences in species diversity values between larval guts at the higher density of 30 larvae per chamber and the ungrazed tiles in the fall experiment ($P < 0.05$). Comparisons of gut diversity and gut evenness values at the higher larval density in the summer experiment with control tiles showed no significant difference. Thus, analyses of gut contents suggested that Glossosoma larvae were selecting certain diatom species rather than acting as generalists.

Chlorophyll a levels (Table 3.3) were not significantly affected by increases in grazer density from 0 to 30 per chamber as reported in the last annual report. There was trend toward increased diatom cell density as grazer pressure increased but the trend was not significant ($P < 0.05$). Conversely changes in organic matter standing crop (expressed as ash free



GRAZER DENSITY(Individuals · chamber⁻¹)

Figure 3.1 Mean cell size of diatoms in periphyton exposed to different grazer densities (Summer, 7-31-85 to 8-6-85 and Fall, 9-10-85 to 9-18-85) (X + S.E.).

Table 3.2 Comparisons of species diversity (H') and species evenness (J) indices calculated from larval gut contents and periphyton on ceramic tiles exposed to three levels of grazer density; 0, 15, and 30 larvae per chamber (X ± S.E., n).

GRAZER DENSITY	TILE SPECIES DIVERSITY	TILE SPECIES EVENNESS	GUT SPECIES DIVERSITY	GUT SPECIES EVENNESS
Summer Experiment (7-31-85 to 8-6-85)				
0	3.18 ± .24 (6)	0.64 ± .03 (6)	—	—
15	2.76 ± .20 (6)	0.58 ± .03 (6)	2.43 ± .31 (3)	0.51 ± .04 (3)
30	3.20 ± .28 (6)	0.66 ± .04 (6)	3.48 ± .22 (3)	0.65 ± .03 (3)
Fall Experiment (9-10-85 to 9-18-85)				
0	3.52 ± .08 (4)	0.68 ± .02 (4)	—	—
30	2.44 ± .29 (4)	0.53 ± .04 (4)	2.23 ± 0.99 (3)	0.50 ± .09 (3)

Table 3.3 Ash-free dry weight (biomass), chlorophyll *a*, and diatom cell density levels measured from ceramic tiles exposed to different grazer densities (X ± S.E., n)

GRAZER DENSITY	AFDW (mg · m ⁻²)	CHL- <i>a</i> (mg · m ⁻²)	CELL DENSITY (No. Cells · m ⁻² · 10 ³)
Summer (7-31-85 to 8-6-85)			
0	805 ± 66.3 (32)	3.40 ± .54 (32)	9.53 ± 1.73 (6)
15	757 ± 19.8 (32)	3.50 ± .49 (32)	12.99 ± 0.79 (6)
30	1,133 ± 117.2 (29)**	3.47 ± .10 (32)	11.81 ± 2.40 (6)
Fall (9-10-85 to 9-18-85)			
0	2,057 ± 260.4 (32)	1.92 ± .21 (32)	8.51 ± 2.38 (4)
30	945 ± 203.4 (32)***	1.59 ± .16 (30)	9.02 ± 3.32 (4)

dry weight-AFDW) were more pronounced but inconsistent (Table 3.3). There was no significant differences in AFDW between the ungrazed tiles and those grazed by 15 individuals per chamber. However, AFDW increased significantly ($P < 0.01$) at the highest grazer density (30 per chamber) in the summer experiment, above levels recorded for both the ungrazed, control tiles and those tiles with a grazer density of 15 per chamber. These findings were reversed in the September experiment with a very highly significant ($P < 0.001$) decrease in organic matter levels on the grazed tiles more than 50% below levels recorded from the ungrazed controls. In September, there was more than 2 fold more organic matter (AFDW) on the ungrazed tiles than was recorded on the ungrazed tiles in the summer experiment.

In summary, 1985 experiments demonstrated that the presence of an insect grazer, Glossosoma nigrum, led to species shifts in the diatom community which affected species composition and diversity and evenness. However, the functional attributes of the community, chlorophyll a and organic matter production, appeared to be less affected.

B. The 1986 Study

These experiments were repeated in 1986 with identical studies conducted at the same time period in August at both FEX and FCD for a control versus 30 Glossosoma per chamber comparison. In addition, two potential new grazers were investigated to see if they would represent better test animals. Only preliminary data are available. Chlorophyll a and organic matter data have been analyzed but the data on diatom density, species composition, etc. awaits analysis.

These experiments were characterized by significantly greater chlorophyll a ($P < 0.001$) at FCD than FEX for both control and treatment (30 Glossosoma) chambers. However, the control was not significantly different from the treatment at either site ($P > 0.05$, Fig. 3.2). Organic matter standing crop did not differ between FEX and FCD (Fig. 3.3), and there were no significant differences between control and treatments at either site.

At FEX, a limpet was used as another potential grazer in the third set of chambers in the random block design (3 treatments per block). Limpets appeared to be much more efficient grazers than did Glossosoma and caused significant reductions ($P < 0.05$) in chlorophyll a compared to either the control or Glossosoma treatments. At FCD, a grazing chironomid was used as the third grazer and, like Glossosoma, caused no significant reduction in either chlorophyll a or organic matter standing crop. The limpet experiments are encouraging so far and, if changes in cell density and species composition are as clearcut as is the chlorophyll a data, this species may be a better choice for future experiments than is Glossosoma.

C. Summary

The 1985 studies demonstrated the feasibility of using streamside flow through channels and tiles colonized in the river to conduct grazer studies. These studies also indicated that Glossosoma nigrum, a caddisfly grazer, was capable of causing species and diversity shifts in the diatom community even though these shifts were not reflected in chlorophyll a or organic matter standing crop data. The species composition shift included a shift towards increased dominance by Achnanthes affinis and decreased abundance by Cocconeis placentula. The

Fig. 3.2 FCD vs. FEX CONTROL AND GLOSSOMATIDAE TREATMENT COMPARISONS

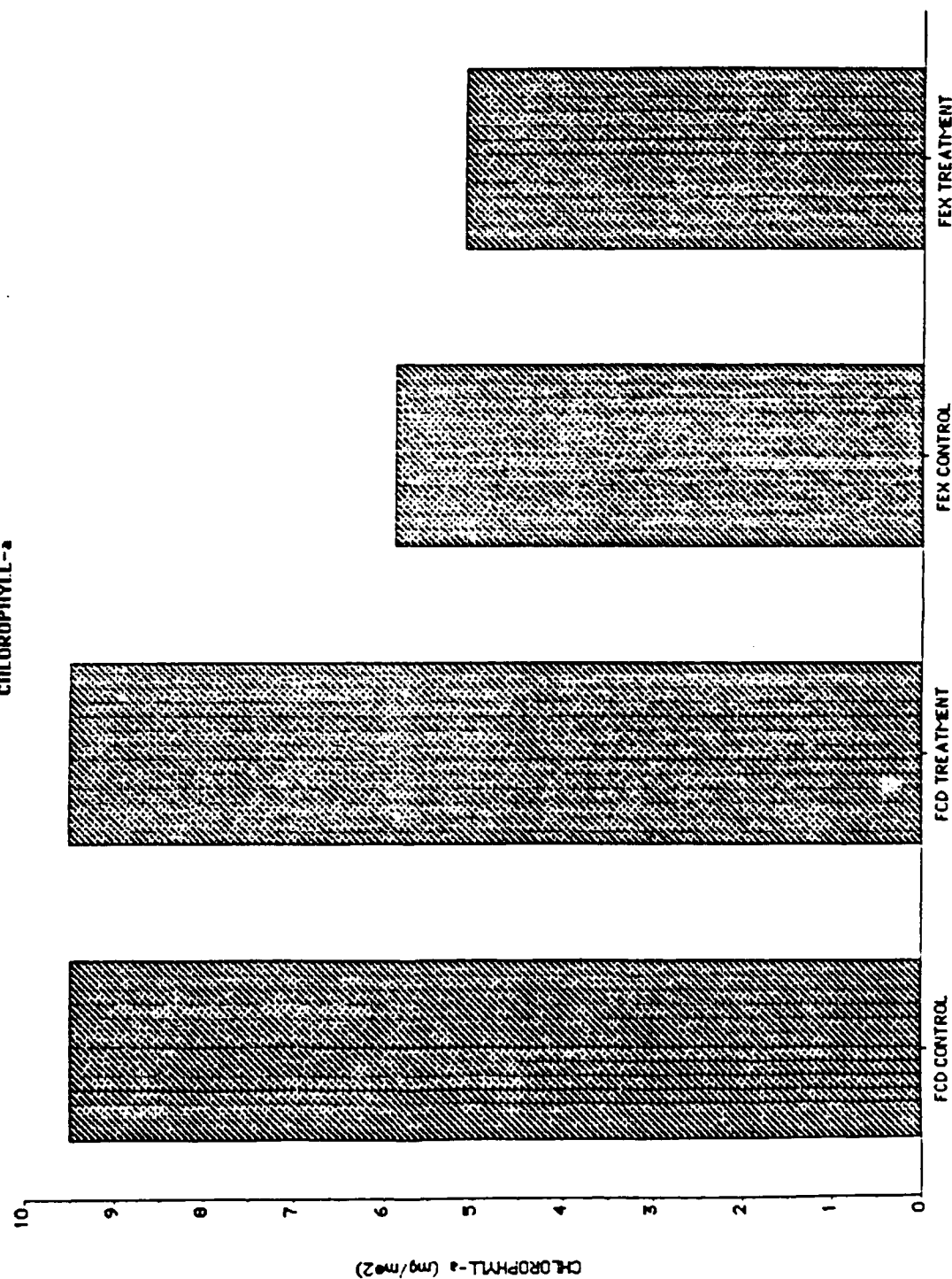
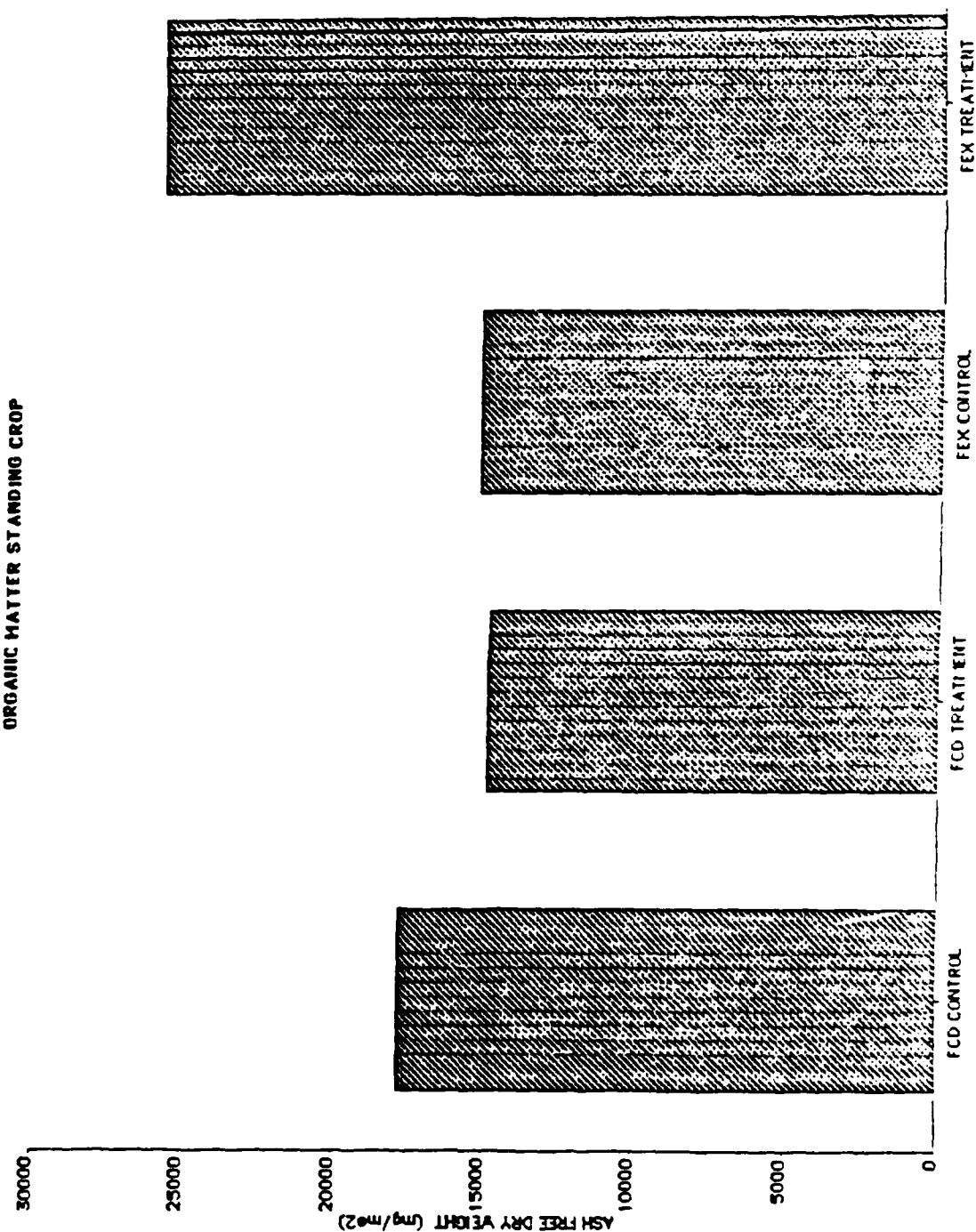


Fig. 3.3 FCD vs. FEX CONTROL AND GLOSSOMATIDAE TREATMENT COMPARISONS
ORGANIC MATTER STANDING CROP



1986 studies were conducted simultaneously at the control (FCD) and experimental (FEX) sites. There were major differences in initial standing crop of chlorophyll a between sites. However, grazing pressure caused no significant shift in standing crops of either chlorophyll a or organic matter. Thus, 1985 data were corroborated. Species counts had not been completed at the time of report preparation. Alternate grazers were also examined. Preliminary experiments indicated that a small limpet may be a very efficient grazer which could be used in future comparisons of ELF effects between sites.

Element 4 - Taxon Richness and Biomass of Stream Insects from Artificial Substrates in Riffles

Changes from the Original Synopsis - None.

Objectives

1) To monitor structural community parameters for benthic insect fauna from July, 1985 to July, 1986 at FEX and FCD sites; 2) to monitor functional community parameters over that time at FEX and FCD sites; 3) to monitor changes in size classes of selected insects over that period at FEX and FCD, and 4) to synthesize 1983 through 1986 data.

Extremely low frequency waves may alter structural and functional community parameters as well as life histories of the benthic fauna. The phenomenon that may be most sensitive to ELF influence could be life history patterns. As all species cannot be monitored, we chose species that fit the following criteria: 1) Found in large numbers (reducing problems of variance); 2) have discrete generation times (enabling tracking of growth phenomena); and 3) are members of functional feeding groups that may respond faster to ELF effects on food resources such as periphyton levels (grazers, collector-gatherers).

Materials and Methods

From 1983 through 1986 60 μ m mesh-lined 18 x 28 x 10 cm open-topped substrate sample baskets were used. They were placed in the same locations at FEX and FCD each year. From June through September of 1985, ten replicates from FEX and ten replicates from FCD were collected at monthly intervals, with sampler replacement after each collection. In September of 1985, 35 samplers were placed in substrates at each site for five collection periods of seven samples per site. After May, 1986, ten samplers were placed in each of the two sites each month after that month's samples were collected until September of 1986. At that time, 35 more samplers for the fall and winter collections of seven replicates per site were placed at FEX and FCD. January and February 1987 collections will be excluded, owing to past difficulties during those months and to low mean variance values in previous years.

Samples were processed by placing samplers in individual buckets, washing sediments thoroughly and retaining the suspended animals in a 60 μ m mesh soil sieve. Animals were preserved in 80% ethyl alcohol. The sediments were replaced in the sampler and then the sampler was replaced in the stream for May through September samples. In September, fresh substrates were used for the fall and winter collections. In the laboratory, insects were picked from detritus and then separated to order level. Specimens

were identified to the lowest taxon possible and then were measured to the nearest mm. for biomass estimates (after Smock, 1980). Numbers of individuals, taxon diversity (H'), taxon richness (S), evenness (J') and percent numerical dominance for selected species were determined for each replicate. Total sample biomass, biomass for functional feeding groups (after Merritt and Cummins, 1984) and mean dry weight per individual (MDW/IND) values were computed. Statistical analyses included power tests, coefficient of variation values, Student-t tests for differences between means, 2-Way ANOVA tests for differences between sites over time for H' , S , J' , correlation coefficient values, and percent dominance of chironomids. MDW/IND values were computed for insects that had high numerical abundances. Those were: Chironomidae, Paraleptophlebia mollis, Ephemerella invaria, E. subvaria, and Optioservus sp. Additional species with high numerical abundances were also analyzed, but changes in size classes over time were random; as no clear pattern emerged, those data are not presented. They included: Baetis macdunnoughi, Ophiogomphus colubrinus, Tipula, and Atherix variegata.

Overall Philosophy Regarding Power Analysis and Environmental Testing

The issue of sample size and power analysis is very complex. The sample variances have several components. Some of the sums of squared deviations are due to sample methodology, some are due to fluctuations in environmental conditions (light levels, flow rates, water temperatures), and some are biological (growth stage). All of these varied effects may change rapidly and dramatically between seasons, months, and even several days' sample collection. This is further complicated when one compares two sites which are not exactly equal, given the fact that we are dealing with a unidirectional (a river) system. The selection of sample size is a trade-off between precision, number of community parameters sampled, and budgetary limitations. Since there are few existing hypotheses identifying specific processes that are affected by ELF fields, the decision was made to include a variety of ecological processes. We have chosen a variety of parameters for robustness rather than focusing on detection of subtle effects on one or two ecological processes. The risk of not including an adequate array is more important than missing subtle shifts with only a few processes requiring large investments of sample analyses. This position is ecologically and socially justified.

The data gathered before the antenna becomes operational represent the baseline pattern of seasonal and annual variation. These data will then be contrasted with patterns observed at the control site after the antenna is functioning. One is not going to be testing ecological differences on a short-term single point basis. The

important ecological patterns are the temporal patterns occurring between seasons and between years. A description of statistical methods for the seasonal data (before and after the antenna is operational appears in the Future Plans section of this element.

Results and Discussion

1985 - 1986 Data

1. Structural Community Indices.-- Taxon diversity, using the Shannon Weiner function (H') was lower in the winter months (November through April) than at other times of the year (Fig. 4.1). H' was significantly higher at FEX than at FCD during that time; however, the two sites were not statistically difference at other times of the year (Table 4.1).

TABLE 4.1
Diversity (H'), Richness (S), and Evenness (J') of Insects
in Substrates at FEX and FCD
(Students' T-Test; Arc Sine Transform for J')

Parameter	July-Oct.85		Nov.85-April 86		April-July 86	
	FEX	FCD	FEX	FCD	FEX	FCD
<hr/>						
H'						
Mean	2.664	2.574	1.819	1.343	2.282	2.263
T	0.553		2.665		0.137	
d.f.	36		44		28	
p value	.2918		.0054**		.4459	
S						
Mean	32.3	30.3	18.0	22.4	42.1	35.6
T	0.727		-2.588		3.870	
d.f.	36		44		28	
p value	.2359		.0065**		.0003***	
J'(arc sine)						
Mean	32.59	32.04	26.13	17.47	25.25	26.40
T	0.317		3.989		-0.701	
d.f.	36		44		28	
p value	.377		.00012***		.2444	

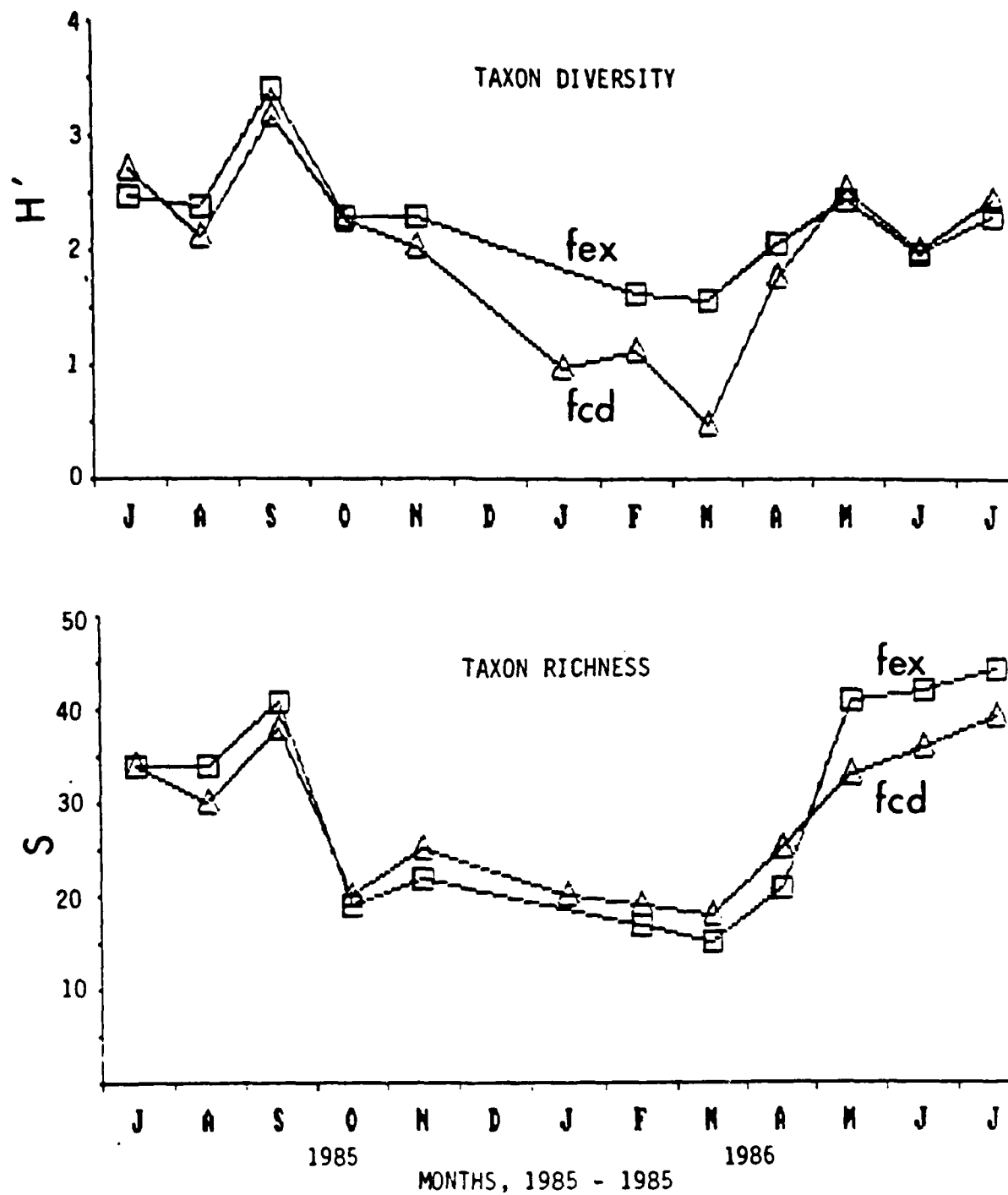


FIGURE 4.1 Mean Diversity (H') and Mean taxon richness (S) at FEX and FCD, July 1984 through July 1986.

TABLE 4.2
Coefficient of Variation Values for Replicate Sets From
July, 1985 through July, 1986; FEX and FCD Combined

Date	Diversity		Richness		Evenness		Number Individ.	
	FEX	FCD	FEX	FCD	FEX	FCD	FEX	FCD
July, 1985	6.4	7.9	14.0	13.4	4.6	9.2	16.1	6.5
August	7.0	7.9	8.6	8.7	5.6	8.9	40.8	17.8
September	3.6	13.8	2.8	9.8	3.4	13.0	10.0	11.7
October	3.4	9.8	12.9	14.6	4.2	13.8	19.4	37.5
November	15.4	15.6	15.0	14.6	11.5	17.0	37.3	29.7
January 1986		15.5		20.5		20.1		60.0
February	19.5	35.7	25.0	29.8	21.2	35.6	96.6	72.2
March	24.4	23.8	34.9	29.1	17.9	16.9	44.3	31.9
April	19.2	30.6	42.2	36.1	31.4	20.2	26.1	60.9
May	10.6	11.0	8.8	5.4	11.4	10.4	33.6	17.5
June	11.1	16.6	11.5	12.9	10.1	13.7	17.9	25.4
July	8.4	11.0	9.4	10.6	7.8	11.6	27.5	24.0

Combined Sites

	H'	S	J'	No.Ind.
Grand Mean	14.28	16.99	13.89	33.24
S.Deviation	8.27	10.67	8.06	21.75
N = 23				

Coefficient of variation values for Diversity (see also Table 4.2) were below 20% except from February through April. Those higher values may be reflect the time of greatest transition for the insect benthos as well as the time when high waters can make collecting of samples difficult. In these time periods, statistical analysis of variation rather than means make the most biological sense. This will be done when the 1983 through the summer of 1987 data are analyzed together.

Taxon richness (S) values were not statistically different between FEX and FCD until November. From November through April, richness was higher at FCD than at FEX. From the late spring-early summer of 1986, richness was higher at FEX than at FCD. The smaller substrate particle size (high in sand content) and slower flow at FCD may be more conducive to winter-tolerant species than FEX. FEX, on the other hand, owing to its greater substrate heterogeneity and flow pattern heterogeneity may be conducive to more summer season species. Coefficient of variation values were below 20% except in February through April of 1986. (See also Table 4.2.)

Evenness (J') values between FEX and FCD -- like H' values -- were only significantly different during the winter and early spring months (Fig. 4.2 and Table 4.1). From

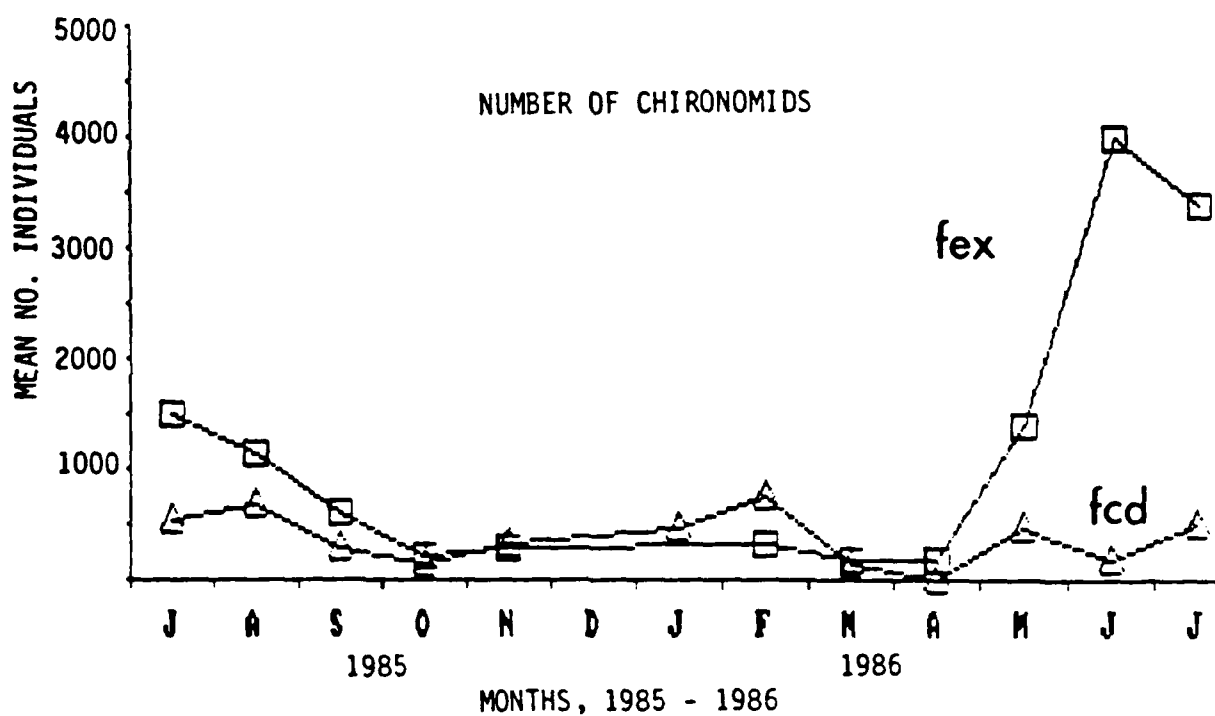
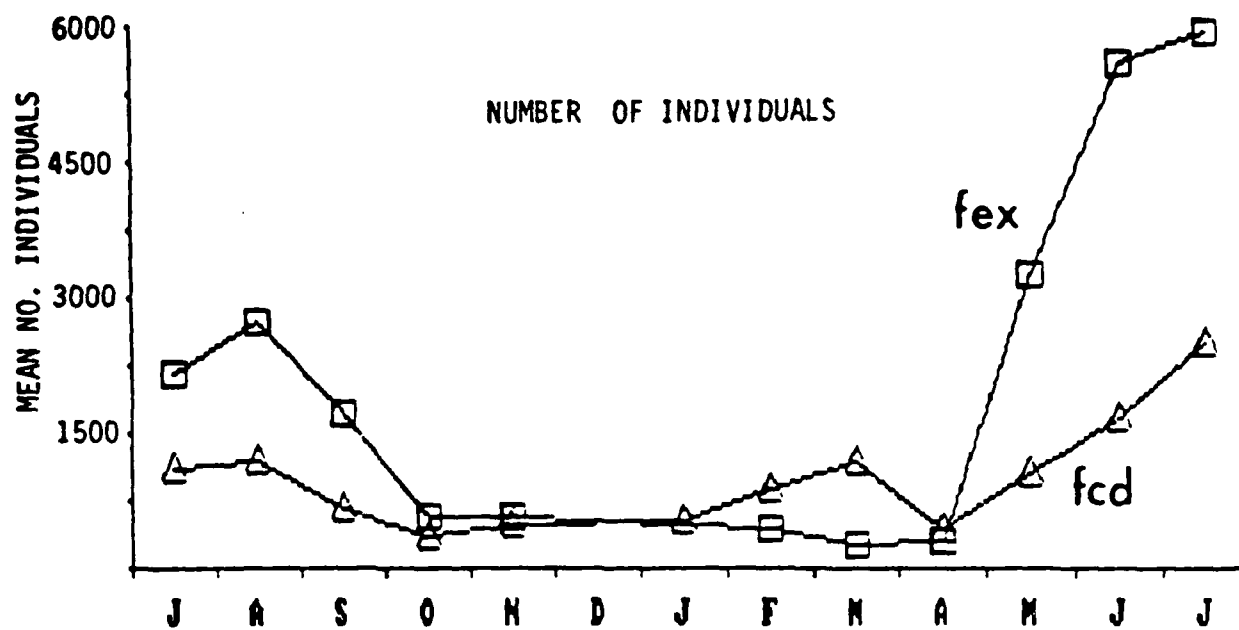


FIGURE 4.3 Mean numbers of individuals and mean numbers of chironomids at FEX and FCD. July 1984 through July 1986.

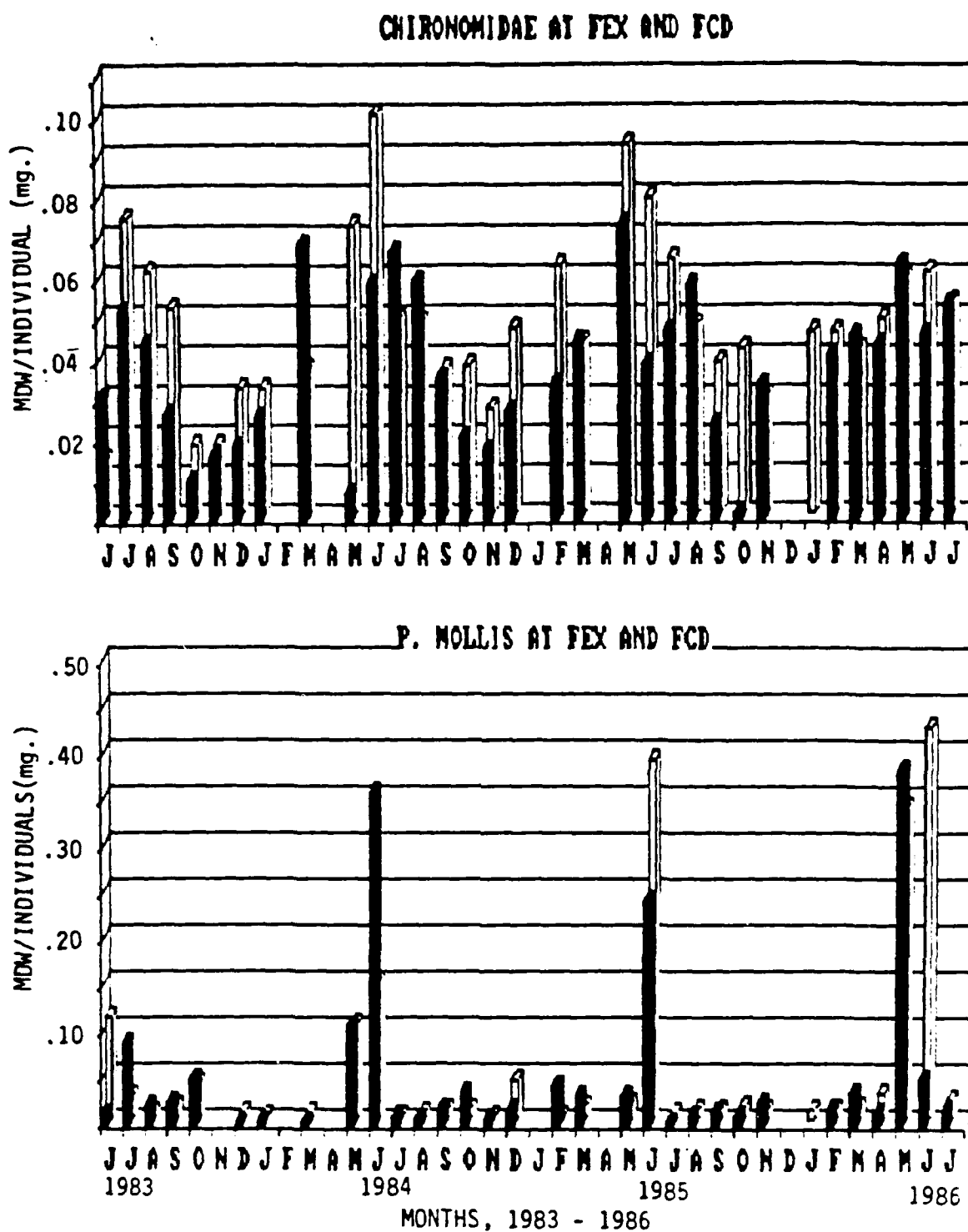


FIGURE 4.4 Mean dry weight per individual for Chironomidae and Paraleptophlebia mollis at FEX and FCD from June 1983 through July 1986.

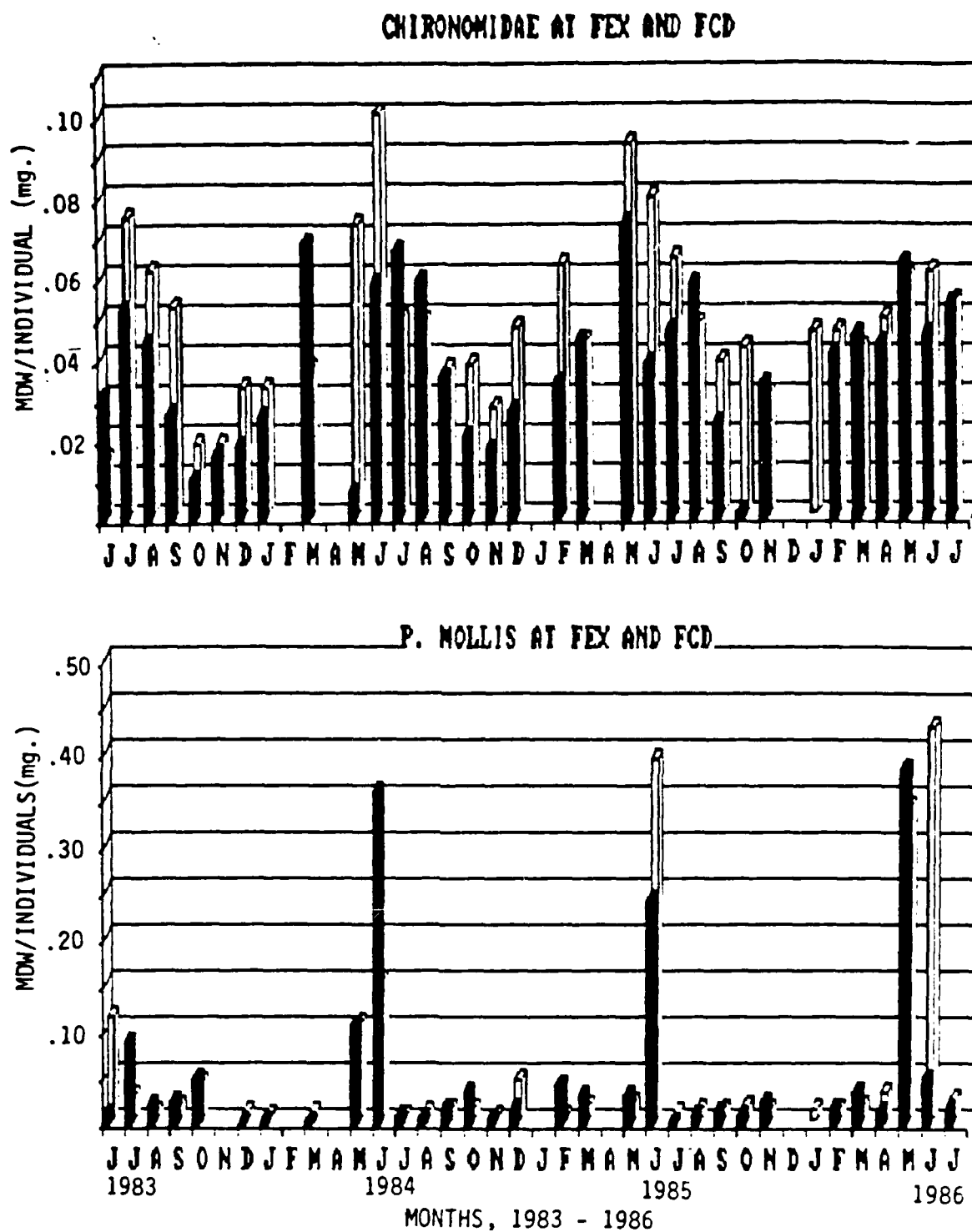


FIGURE 4.4 Mean dry weight per individual for Chironomidae and Paraleptophlebia mollis at FEX and FCD from June 1983 through July 1986.

number of individuals for this species was highest in August (114 per replicate at FEX and 176 per replicate at FCD in 1986). Apparently, eggs hatch slowly over the summer, as no mature nymphs were taken after June. Also, nymphs remained small throughout the winter and early spring. Accelerated growth appears to occur over a one to two-month period in the late spring. If ELF seriously affects this species, either in numerical abundance or via seasonal growth patterns, they should be detectable.

c. Ephemerella invaria (Walker) and Ephemerella subvaria McDunnough. There are distinctive size class patterns for each species (Fig. 4.5). Ephemerella invaria was most abundant in October, when its MDW/IND values were very low. It appears to be univoltine, with its major emergence being in May and June in 1986. A comparison with data for this species from Element 6 (leaf processing) shows that the size classes are similar, an expected result.

Ephemerella subvaria's growth pattern, as inferred from size class data, ascended until May, after which time, no individuals were found or identified as this species until July of 1986. Each of the two species had a similar size class pattern at FEX and FCD. The two species will continue to be monitored.

c. Optioservus sp. No clear pattern emerges for this collector-gatherer elmids. This genus is not univoltine. Even though this genus does not meet the criteria of having discrete generations, we will continue to use it, as it has high numbers and we can gather considerable information as to larval and adult numbers as the genus is holobiotic. There is a tendency for larger larvae to occur in the winter (Fig. 4.6). Certainly, from April through October the MDW/IND values were lower.

Numbers of adults and larvae were highest from June through September each year (Fig. 4.7). Mean number of larvae and adults for the two sites shown in that figure illustrate a trend. Number of larvae were high in the summer and low in the winter and spring. Adult numbers were high just prior to larval increase in numbers, especially evident at the FEX site.

Overall Comparisons with 1983 - 1984 Data

1. Structural Community Parameters.-- H' and J' show consistent depressions during the winter and early spring months at FCD (Figure 4.8). J' and H' are correlated inversely with respect to numerical dominance of the family Chironomidae (Fig. 4.2; Table 4.3a). When H' and J' values go down during the winter months, percent dominance of chironomids increases, especially at the FCD site. Given the power that chironomids may have on structural community parameters (not having the person power to identify the

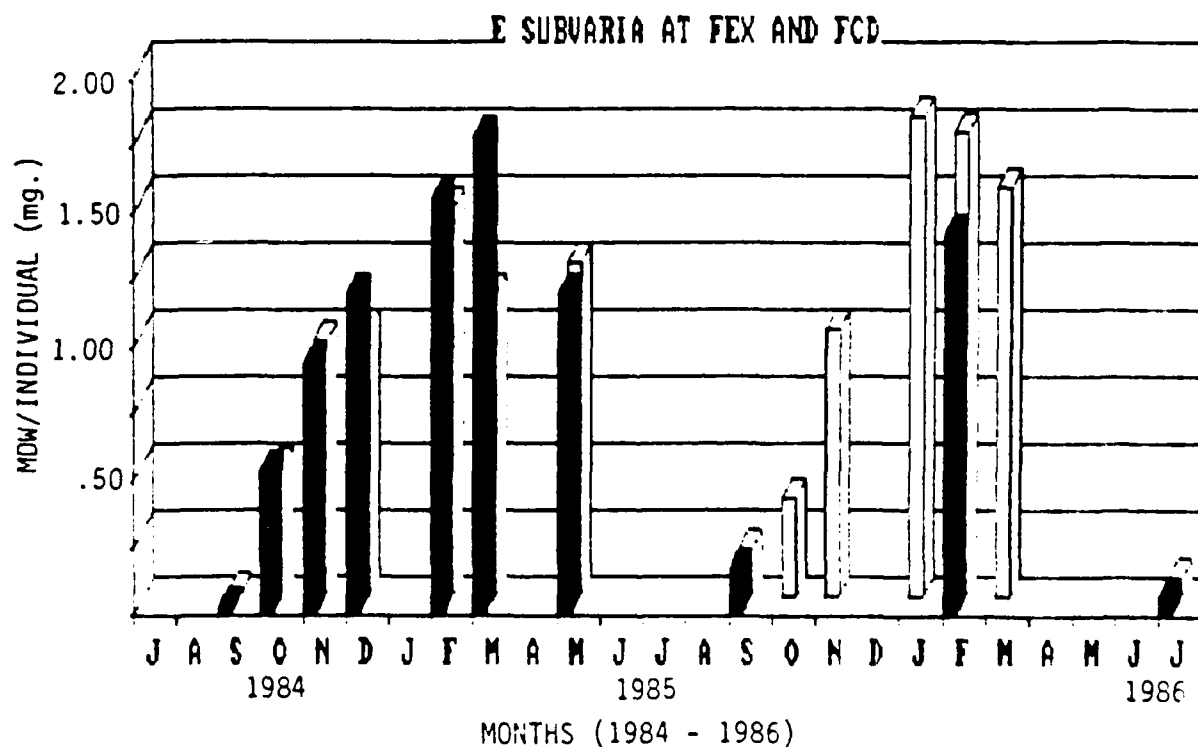
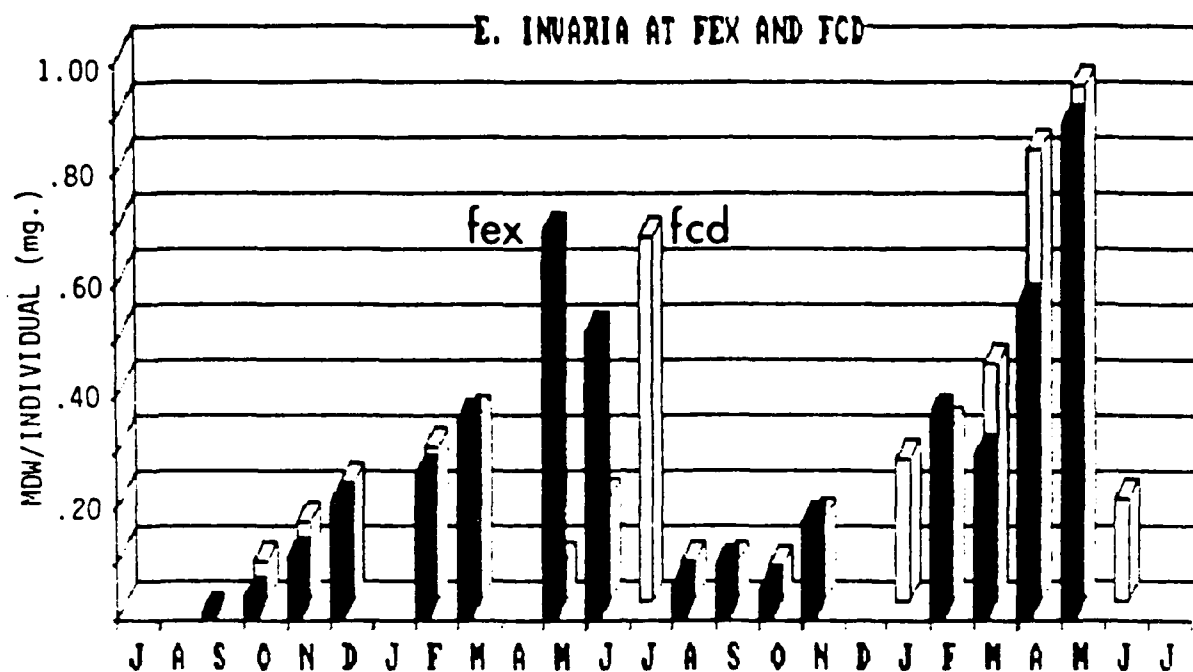


FIGURE 4.5 Mean dry weight per individual for *Ephemerella subvaria* and *Ephemerella invaria* at FEX and FCD from June 1983 through July 1986.

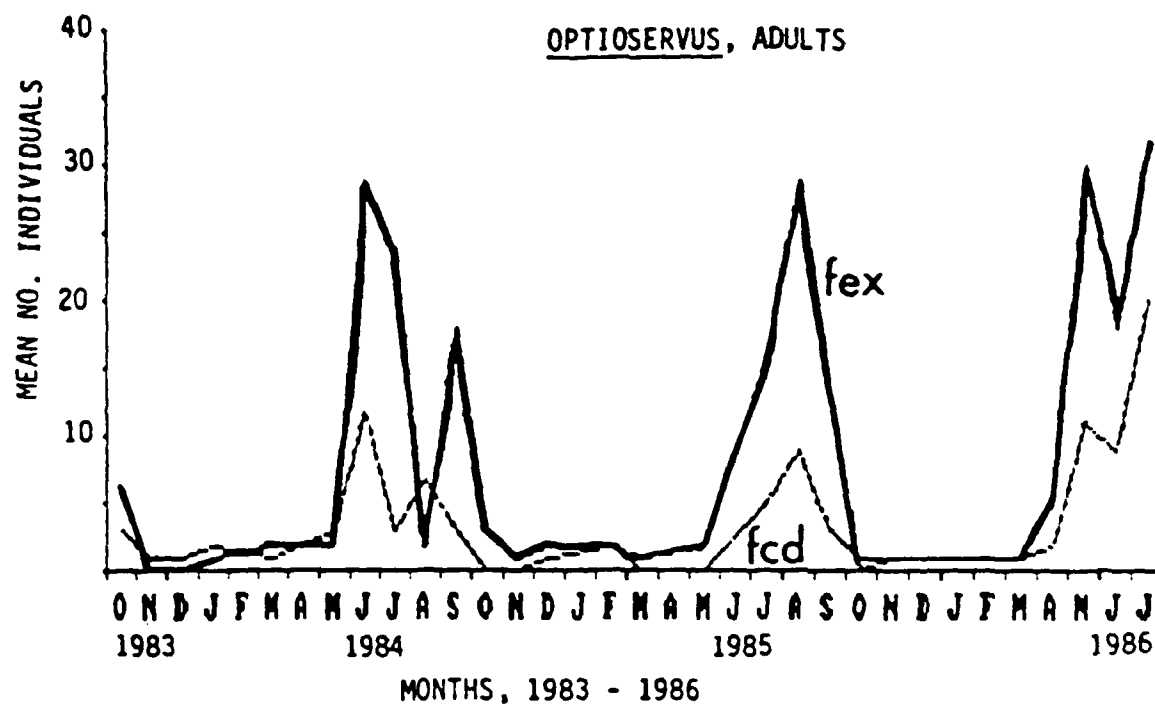
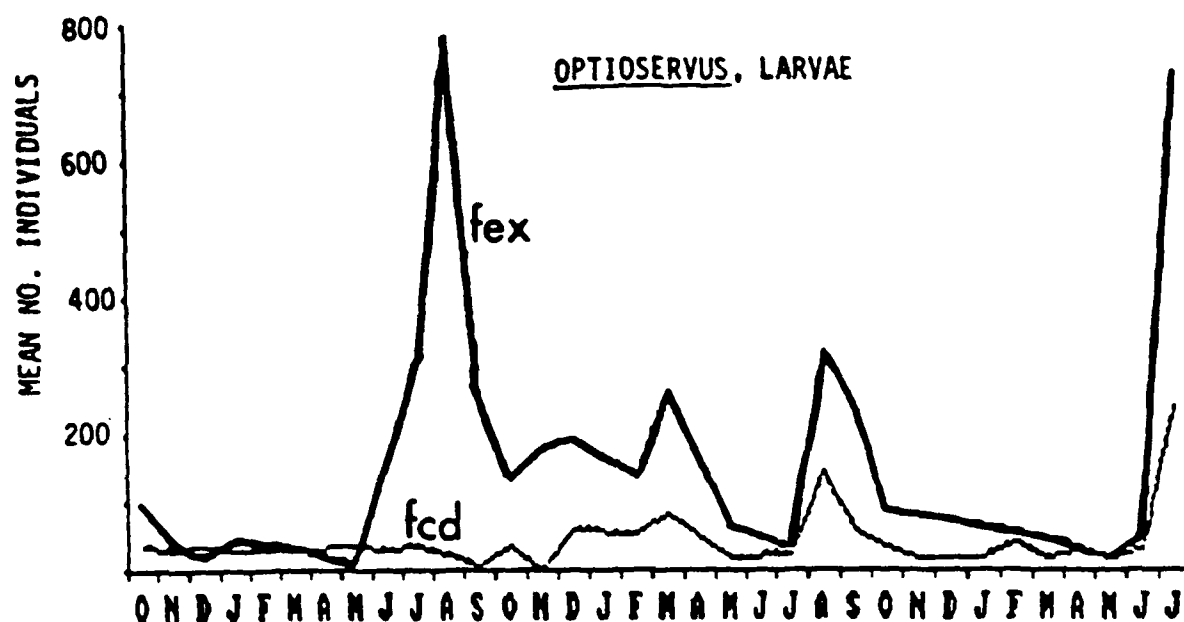


FIGURE 4.7 Mean numbers of larvae and mean number of adults of Optioservus at FEX and FCD from July, 1984 through July, 1986.

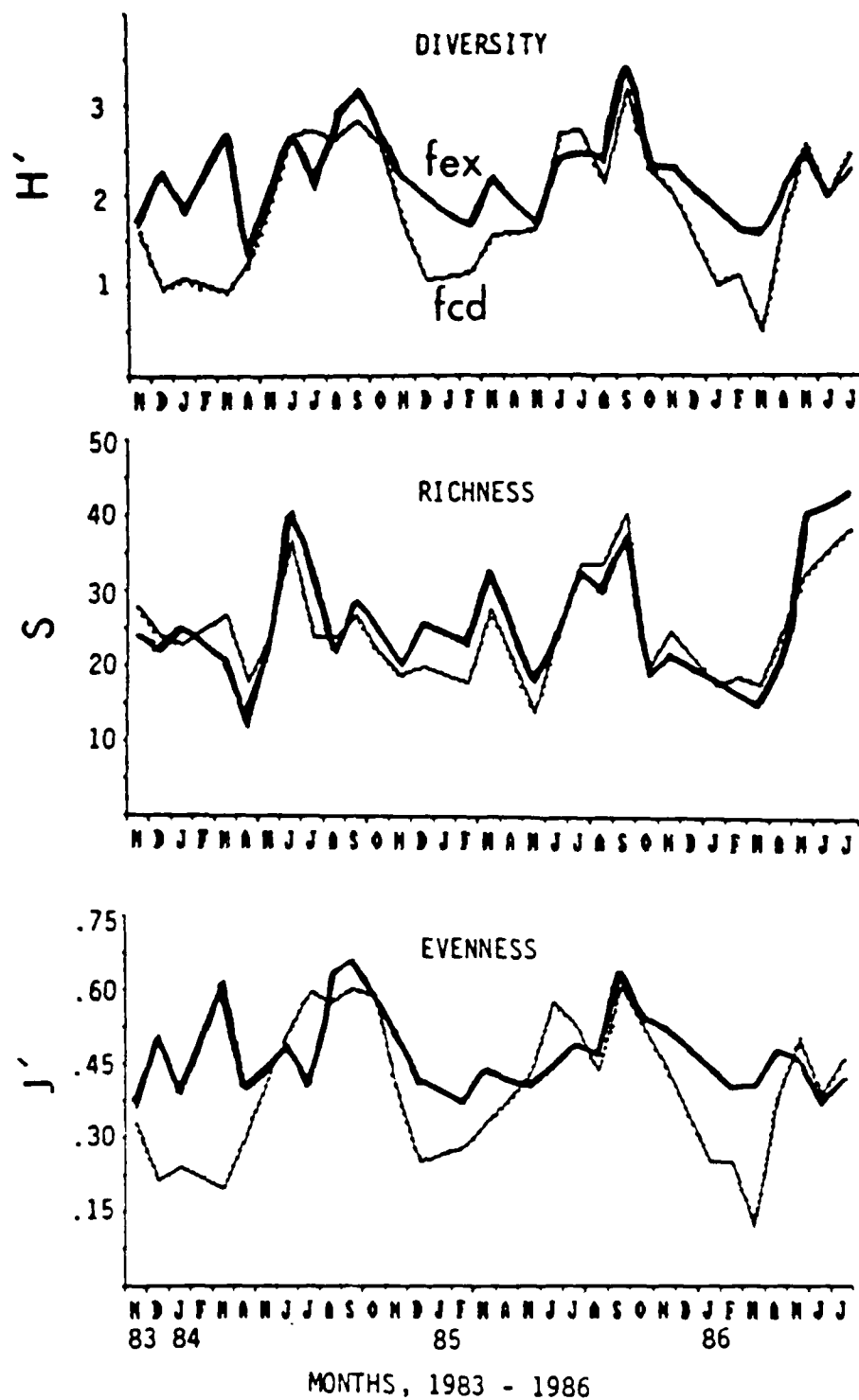


FIGURE 4.8 Taxon diversity (H'), evenness (J') and richness (S) at FEX and FCD from November, 1983 through July, 1986.

chironomids below the family level), all structural community parameters were recomputed without chironomids. They appear in Table 4.3b. The correlation coefficients for each parameter between sites as well as correlation coefficients between parameters at the same site were higher when chironomids were included except for the correlation coefficient for J' at FEX versus FCD. In that case, the values were lower when chironomids were included. This indeed makes sense, as chironomids as a group include many numbers. Those numbers depress the J' values as well as the H' values, but have no effect on taxon richness. Lastly, percent dominance values (arc sine transformed data) have more effect on J' at FCD than on J' at FEX. There simply are more chironomids at FCD during the winter months -- a time when numbers of other individuals are at their lowest -- than at FEX. (See figures 4.2 and 4.3).

Taxon richness tends to be lowest in the spring (March - May). Whether the troughs occur in March - April or in April - May may depend on timing of water temperature rises in the spring. (See Figure 4.10 for reference). When water temperature rose early (April, both in 1984 and 1986), troughs for taxon richness occurred in March-April. In 1985, water temperature stayed low longer; the low was in June

TABLE 4.3a
Correlation Matrix for Structural Community Parameters.
Insects (including Chironomids) in Substrates from
July, 1983 through July, 1986

	FEX S	FCD S	FEX H'	FCD H'	FEX J'	FCD J'	FEX %Chiro	FCD %Chir*
FEX,S	1.00							
FCD,S	.90	1.00						
FEX,H'	.50	.56	1.00					
FCD,H'	.62	.59	.69	1.00				
FEX,J'	.05	.19	.88	.88	1.00			
FCD,J'	.43	.36	.62	.96	.47	1.00		
FEX, %Chironomids			-.72	-.63	-.67	-.62	1.00	
FCD, %Chironomids			-.55	-.93	-.37	-.94	.69	1.00

* Percent numerical dominance of Chironomidae relative to total numbers of all individuals.

Critical value (1-tail, .05) = + or - 0.318

Critical value (2-tail, .05) = + or - 0.373

TABLE 4.3b
Correlation Matrix for Structural Community Parameters.
Insects, Excluding Chironomids, in Substrates from
July, 1983 through July, 1986

	FEX S	FCD S	FEX H'	FCD H'	FEX J'	FCD J'
FEX,S	1.00					
FCD,S	.90	1.00				
FEX,H'	.47	.39	1.00			
FCD,H'	.52	.54	.62	1.00		
FEX,J'	-.12	-.09	.75	.38	1.00	
FCD,J'	.02	.02	.45	.82	.51	1.00

Critical value (1-tail, .05) = + or - .318

Critical value (2-tail, .05) = + or - .373

2. Functional Community Indices.-- Figure 4.9 shows changes in total insect biomass at FEX, at FCD and at FEX and FCD combined. Figure 4.10 shows changes in total insect biomass, diatom density and water temperature from June of 1983 through September of 1986. (The values are grand means for the two sites combined). There are four distinct summer peaks and three fall-winter troughs for all three parameters. The summer peaks dropped from 1983 to 1985. In 1986, when the Upper Peninsula had both an early spring and a dry spring and summer, insect biomass and diatom densities were at their highest. Table 4.4 presents the statistical analysis for Figure 4.10. (The means were not independent of the variances for the total insect biomass data and so a natural log transformation was performed prior to the regression analyses.)

TABLE 4.4
Linear Regression Analysis for Insect Biomass, Diatom
Density and Water Temperature, 1983 - 1986

A. June 1983 - July 1986	r ²	Significance
Insect Biomass vs. Diatom Density	.523	p<.00001****
Insect Biomass vs. Water Temperature	.540	p<.00001****
Diatom Density vs. Water Temperature	.548	p<.00001****
B. June 1983 - May 1984		
Insect Biomass vs. Diatom Density	.610	p<.005***
Insect Biomass vs. Water Temperature	.678	p<.002***
Diatom Density vs. Water Temperature	.723	p<.009***
C. May 1984 - June 1985		
Insect Biomass vs. Diatom Density	.548	p<.01*
Insect Biomass vs. Water Temperature	.678	p<.03*
Diatom Density vs. Water Temperature	.389	p<.05*

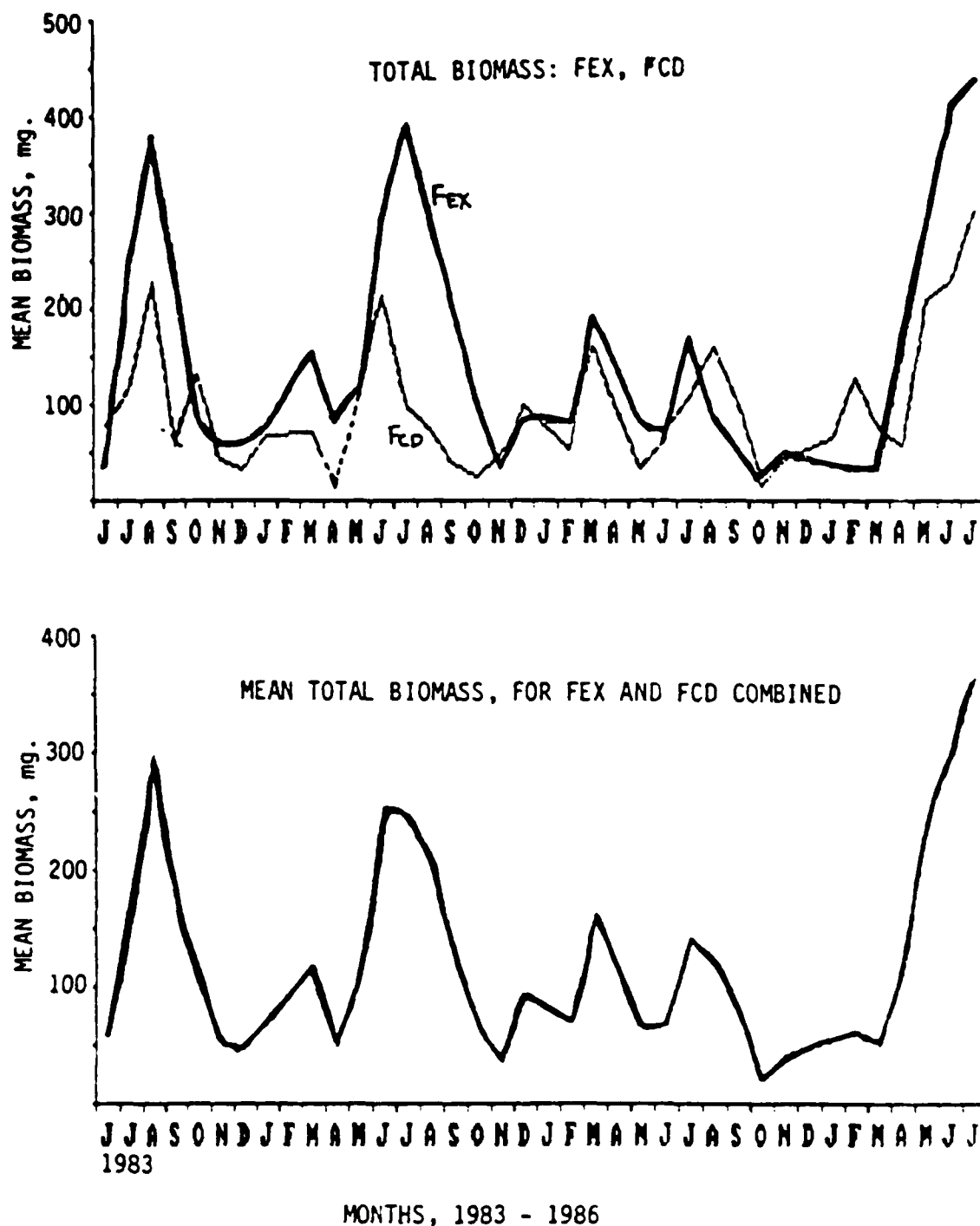


FIGURE 4.9 Changes in insect mean total biomass (mg) at FEX and at FCD.

Grand mean changes in insect total biomass (mg) for FEX and FCD combined.

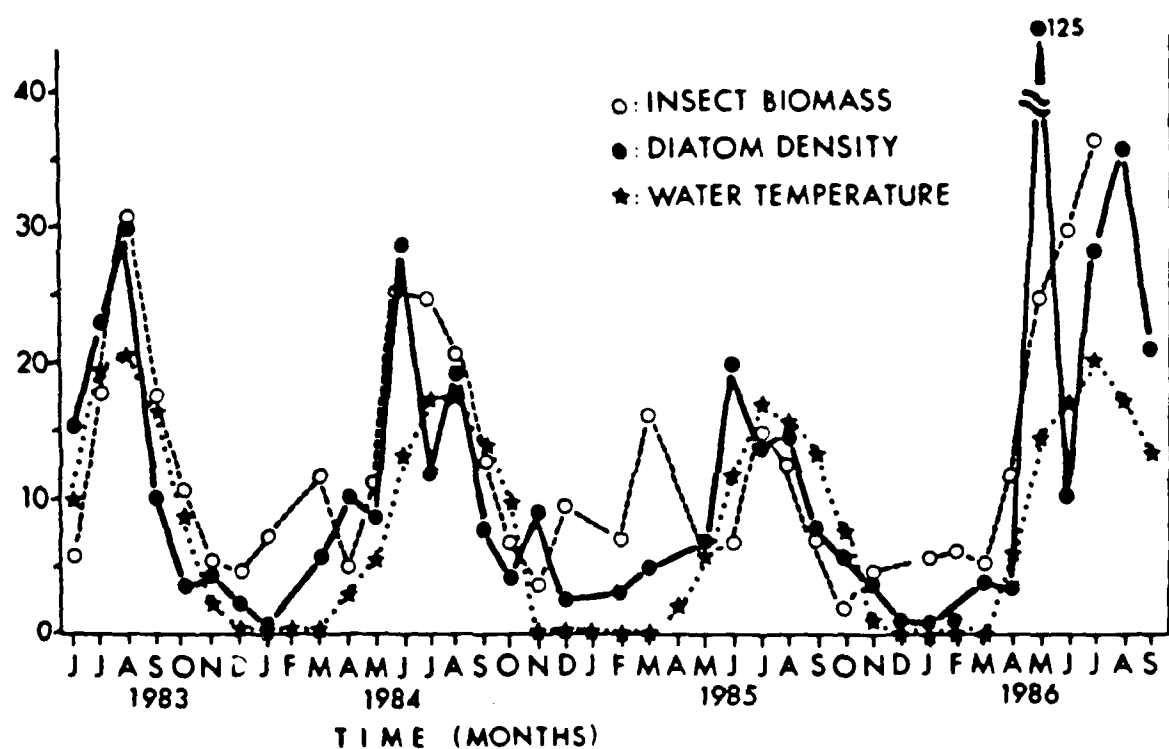


FIGURE 4.10 Changes in insect mean total biomass (mg./sample $\times 10^{-1}$, diatom density (number per square meter $\times 10^6$), and water temperature ($^{\circ}\text{C}$) for FEX and FCD combined. June, 1983 through September, 1986

Table 4.4 continued

D. July 1985 - July 1986	r ²	Significance
Insect Biomass vs. Diatom Density	.595	p<.003***
Insect Biomass vs. Water Temperature	.594	p<.003***
Diatom Density vs. Water Temperature	.544	p<.006***

Not only were the regression coefficients high for the linear regressions, but the levels of significance were very high as well. Because the trends are so predictable, further work along these lines will be done.

Insect total biomass values were separated according to functional feeding groups to see which groups had the most influence on the total biomass patterns. Table 4.5 presents the correlation coefficients for the functional feeding groups with respect to total biomass and diatom density within sites. Table 4.6 presents the values for the parameters with respect to FEX versus FCD.

The following defines the abbreviations used in Table 4.5:
C-F = Collector-Filter Feeders; C-G = Collector-Gatherers,
Shred. = Shredders; Pred. = Predators

TABLE 4.5
Correlation Coefficients for Insect Functional Feeding Groups
as Related to Diatom Density and Total Insect Biomass

	C-F FEX	C-F FCD	C-G FEX	C-G FCD	Shred. FEX	Shred. FCD	Pred. FEX	Pred. FCD
Diatom Density	.623	.748	.593	.500	.169	.330	.510	.510
Insect Biomass	.767	.617	.769	.357	.093	.611	.831	.945

Critical value (1-tail, .05) = + or - .292

Critical value (2-tail, .05) = + or - .343

TABLE 4.6
Correlation Coefficients for Insect Total Biomass, Diatom
Density and Functional Feeding Group Biomass at
FEX Versus FCD

	Total Insect	Diatom Density	C-F	C-G	Shred- ders	Predators
FEX versus FCD	.530	.648	.242	.640	.288	.478

Figure 4.11 shows that the seasonal pattern for collector-gatherers did indeed follow the general pattern for total insect biomass (C.C. = .769 at FEX and .357) at both sites (C.C. = 0.640). However, the shredders (lower panel of same figure) did not, either within or between the sites (also tables 4.5, 4.6). Collector-gatherers had summer peaks, but shredders (who would more likely be associated with leaves than substrates) had both summer and winter peaks.

Figure 4.12 shows that the seasonal pattern for predators followed the general pattern for total insect biomass (C.C. = .831 at FEX and .945 at FCD) at both sites (C.C. = .478). Much of the biomass for predators comes from the dragonfly, Ophiogomphus colubrinus. This species has a life cycle that exceeds a year in streams; thus, individuals would be expected to occur year-round. Yet, they are more common and are larger in substrates taken in the summer. It is possible that they move to areas outside of substrates toward the center of the river during the colder periods of the year. This is the most parsimonious explanation for the results with respect to predator biomass. Collector-filter feeders (in the lower panel of the same figure) followed the seasonal trend found in total insect biomass (C.C. = .767 for FEX and .617 for FCD); however, there was a difference with respect to the two sites (C.C. = .242). The peaks tended to be higher at FEX and the timing differed enough to reduce the correlation coefficient values where FEX and FCD were contrasted for this functional feeding group.

Figure 4.13 shows a distinct seasonal pattern for the family Glossosomatidae, and a pattern that is similar to the overall insect biomass pattern illustrated in Figure 4.10. This family includes Glossosoma and Protoptila. As the numbers of individuals over time track the seasonal peaks and troughs of diatom density, temperature, and total insect biomass, these collector-gatherers will be added to our list of taxa to be detailed.

Future Plans for This Element

The same design and accumulation of data will continue as in the past. We have added more replicates for our collection dates (seven to 10 as opposed to five in the past). However, we have processed more than five only for the late fall and winter samples thus far. The late spring and summer samples are so large that one sample takes at least three times as long as samples taken at other times of the year. If time permits during the winter months, those unpicked summer samples will be processed.

The principle change for next year will be in the form or more sophisticated analyses. We have requested that ambient monitoring data be made available on a monthly basis in the

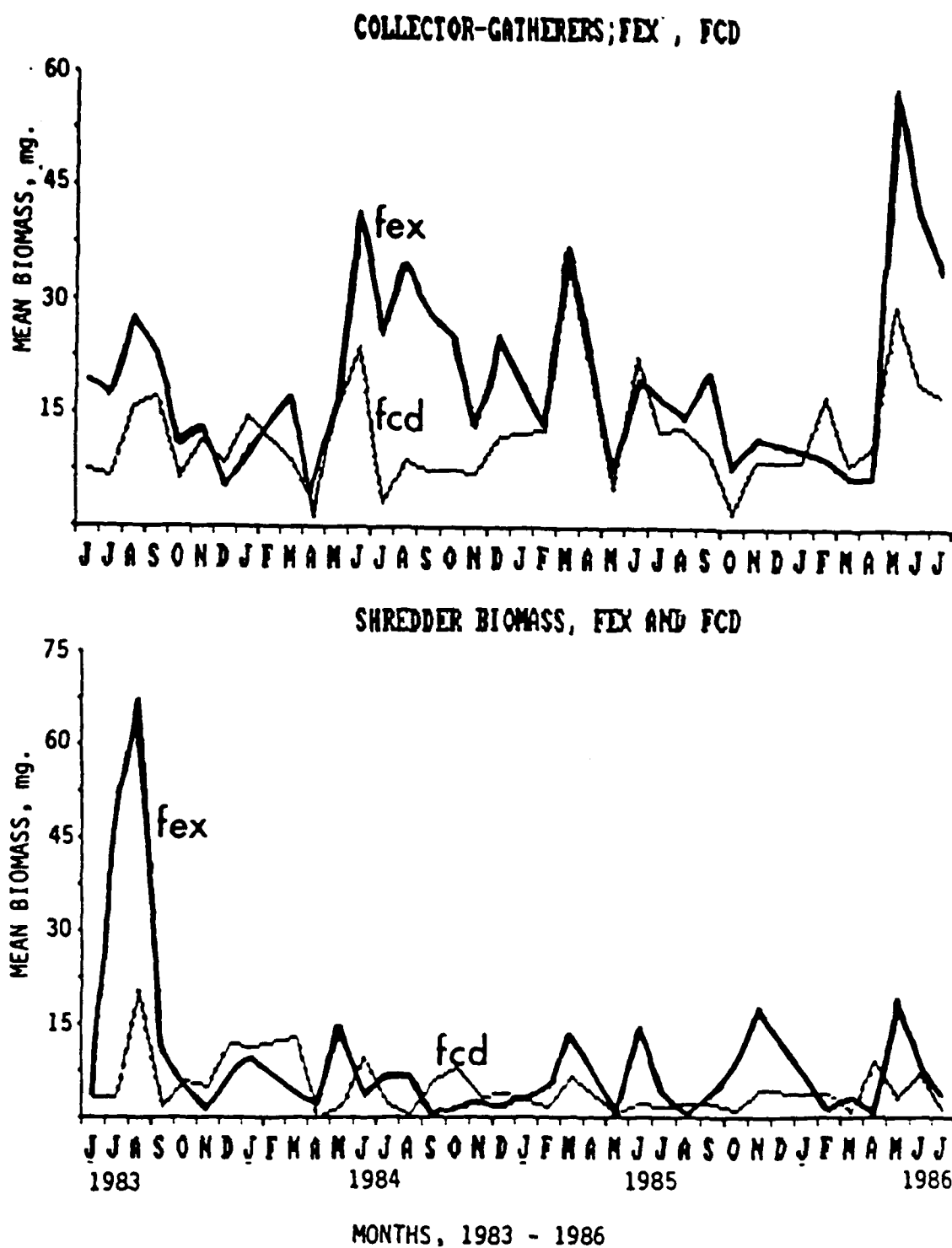


FIGURE 4.11 Changes in collector-gather and shredder biomass (mg./sample) at FEX versus FCD. June, 1983 through September, 1986.

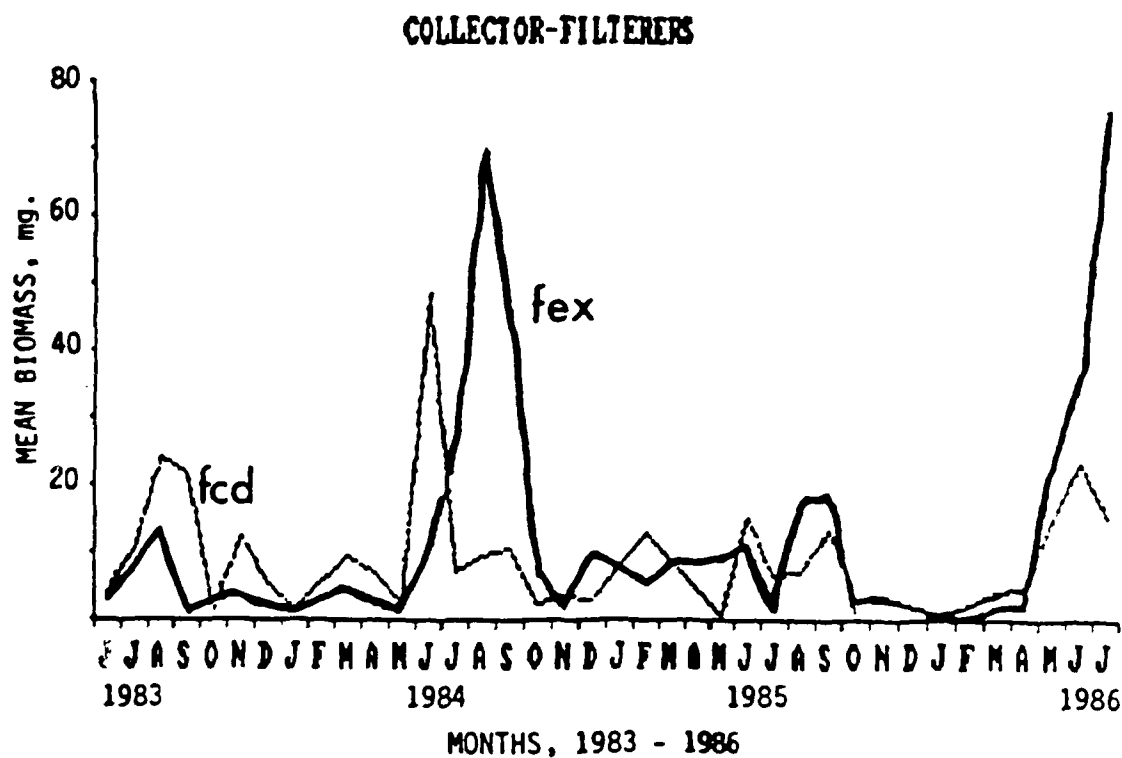
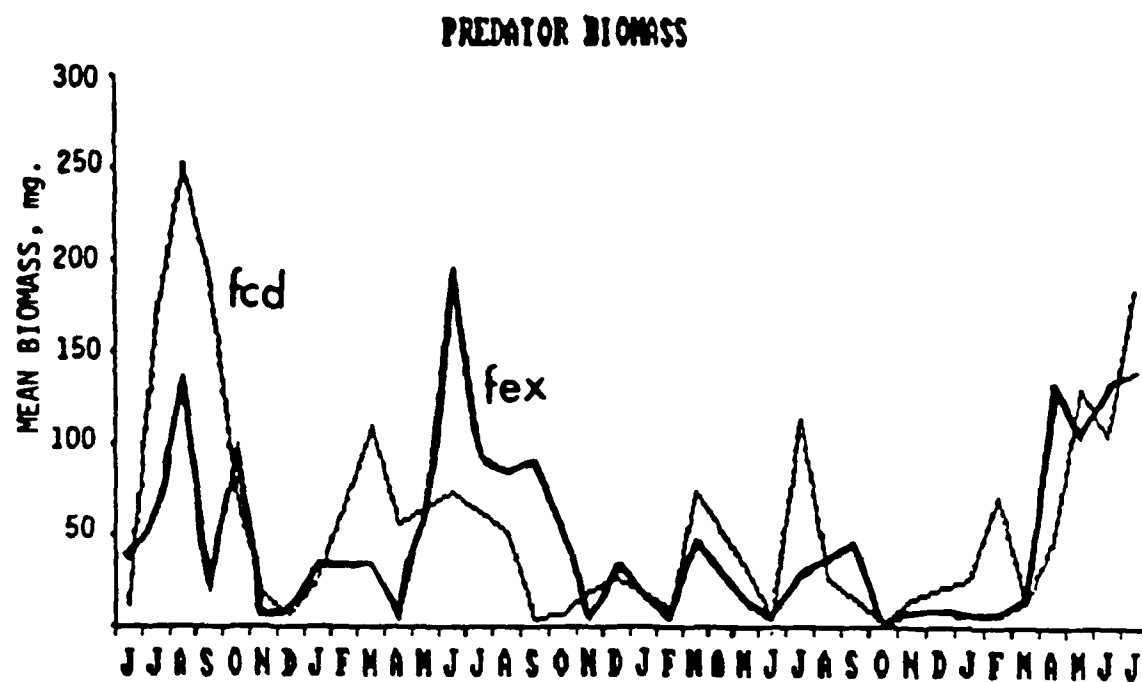


FIGURE 4.12 Changes in predator and filter-feeder biomass (mg/sample) at FEX versus FCD. June, 1983 through Sept., 1986.

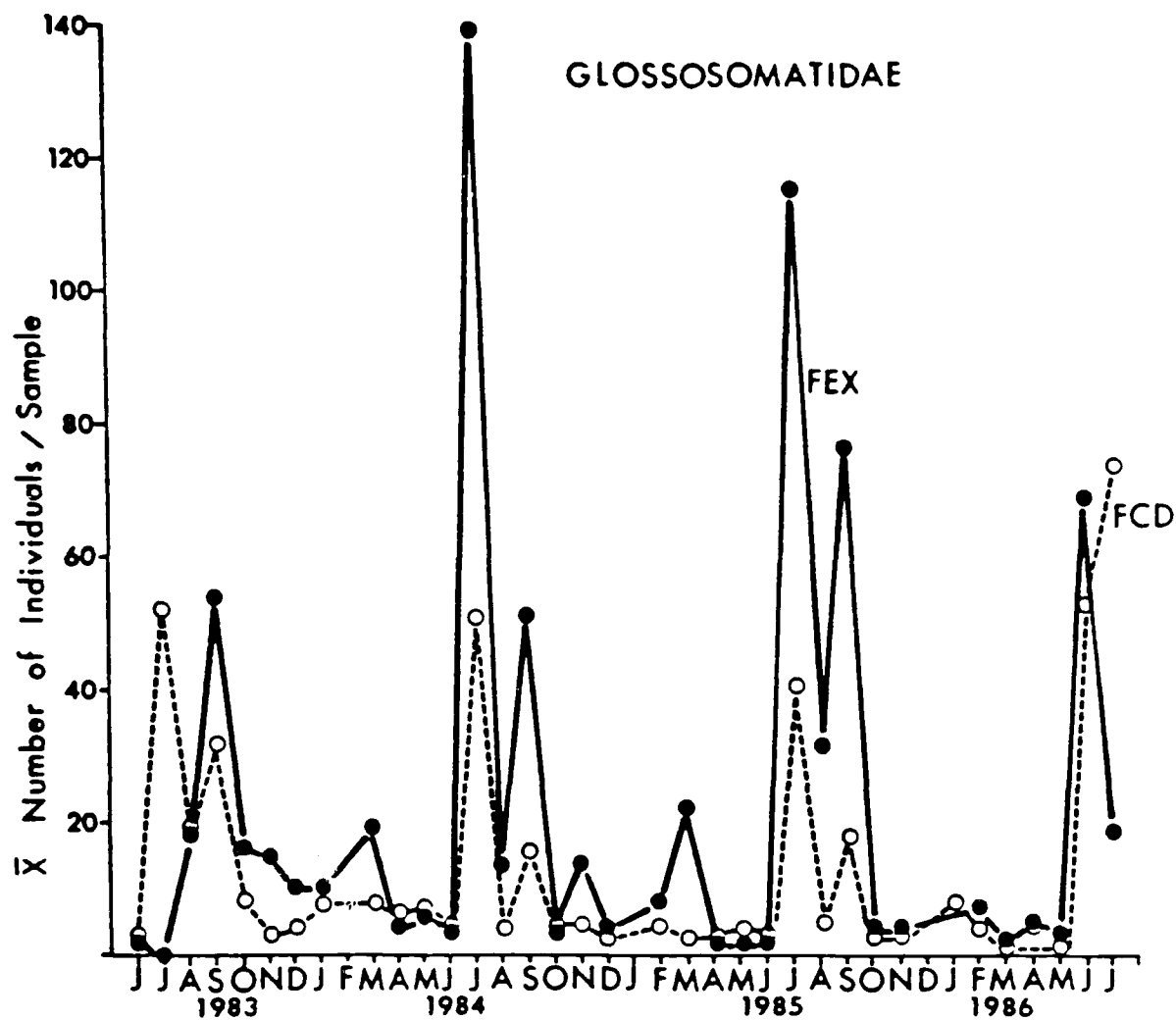


FIGURE 4.13 Numbers of individuals per sample of *Glossosoma* sp. and *Protoptila* sp. (Glossosomatidae) at FEX and FCD from July 1983 through July 1986.

future so that some of these analyses can commence this coming summer rather in the fall. By the end of the 1987 summer season, we should have five year's worth of pre-operation data (i.e., without the lines being fully operational). We will take the most consistent data sets and regress integrated degree days (water temperature appears to be the best temperature data to use) against them. This will be done for the means and for the variances for the integrated degree days. There are many times when the variances "give more information" than the means with these sorts of biological data -- biological transition times being one of the most critical -- so variances will be analyzed around those times. After regressions are completed, where necessary, they will be linearized. That way, FEX and FCD can be compared for differences in slopes. After the ELF lines are operational, before and after slopes will be compared, both between FEX and FCD and within the sites before and after ELF has been activated.

We will also look at differences between abundances at FEX and FCD, using a BACI (Before and After at Control and Impact sites) design (Stewart-Oaten et al. 1986) or a Box-Jenkins time series intervention analysis (Hipel et al., 1978). In the first analysis, the difference between the means are plotted rather than the means themselves. If there is no change, one would expect a horizontal line. Changes would be reflected in the direction, amplitude, and frequency of change. In the second analysis, the design tests whether a man-induced intervention causes a significant change in the mean level of a time series. This analysis permits effects to be estimated either as parameter differences or as the ratio between treated and control reaches. (The last design was suggested by a reviewer.)

Summary

Taxon diversity (H') and evenness (J') from 1983 to 1984 were highly correlated with one another. Both parameters had their highest values in the summer months and their lowest values during the winter months. High chironomid abundances greatly affected H' and J' and are highly correlated with those two parameters. When chironomids were excluded from benthic insect analyses, correlation coefficients for J' with respect to H' were lower -- especially at FCD, which is the site containing high numbers of chironomids relative to other species abundances.

Distinct seasonal patterns were found for insect total biomass over a four year period. These patterns were highly correlated with diatom densities and water temperatures at FEX and FCD combined. Changes in biomass values over seasons for the functional feeding groups, collector-gatherers, collector-filter feeders, and predators were highly correlated with diatom densities. Shredder biomass

values were not. These seasonal patterns will continue to be investigated, using additional ambient monitoring data.

Biomass values, when coupled with numerical abundances of certain taxa, showed low in variance over time. The following taxa showed consistent size class patterns (DW/IND) from 1983 to 1986 at both sites: Chironomidae, Paraleptophlebia mollis, Ephemerella invaria, E. subvaria, and Optioservus sp. They will continue to be monitored. Additionally, two collector-grazers, Glossosoma sp. and Protophila sp. will be included in the future as both species meet our requirements. Because Optioservus is not a univoltine genus but both adults and larvae are found in samples, separate analyses as to adult/larval ratios will be performed. DW/IND data for this genus is less reliable than those data for other species, given the fact that there is generation overlap.

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Element 5 - Movement Patterns of Selected Aquatic Invertebrates

Changes from the Original Synopsis - None.

Objectives

To monitor short-term movement patterns of a dominant insect predator, the dragonfly Ophiogomphus colubrinus.

Just as ELF can affect orientation and movements of birds, mammals and fish, it can also affect movements and orientations of aquatic insects. Given the effort necessary to monitor movement patterns, we selected a highly abundant predator whose normal travel distances are short enough to study feasibly. If ELF alters orientation and movement rates of this predator, we expect that, with the numbers of individuals used and with our high mark-recapture success, to be able to detect differences under the influence of ELF.

Materials and Methods

In June, July and August, 1986, movement studies of naiads of the dragonfly, Ophiogomphus colubrinus, were conducted at FEX and FCD. The same riffles at FEX and at FCD were used in 1986 as was used in 1984 and 1985.

Prior to initiating mark-recapture studies, one meter square grids were established, using flagged metal stakes. Flow rates, direction of flow patterns, and water depths were taken, using the stakes as reference points. Flow rates were determined with a Gurley Flowmeter; flow directions by mapping the movement of an orange as it travelled between stakes along the length of the streamcourse. Depths were taken at one meter intervals across widths 0 (release line), 2, 4, 6, 8 and 10 m downstream from the release point and thereafter every five meters downstream from the release point.

Naiads were then collected from riffles at least 200 m upstream from the study site. Naiads were placed in holding pans with stream water until sufficient numbers had been collected -- at least 300. They were removed from the holding pan, blotted dry with a "Kimwipe", and marked with Testors enamel paint on the dorsal and lateral surfaces of the abdomen. The marked animals were then placed in a second holding pan and allowed to dry. After drying, the naiads were placed in a third holding pan with fresh stream water to bring them to ambient stream water temperature prior to release.

The animals were taken to the upper end of the study grid and released in the meter square area denoted with asterisks in figs. 5.1 and 5.2. Care was taken to keep the animals within the release area by holding a handscreen just downstream to catch any animals that floated beyond the release site.

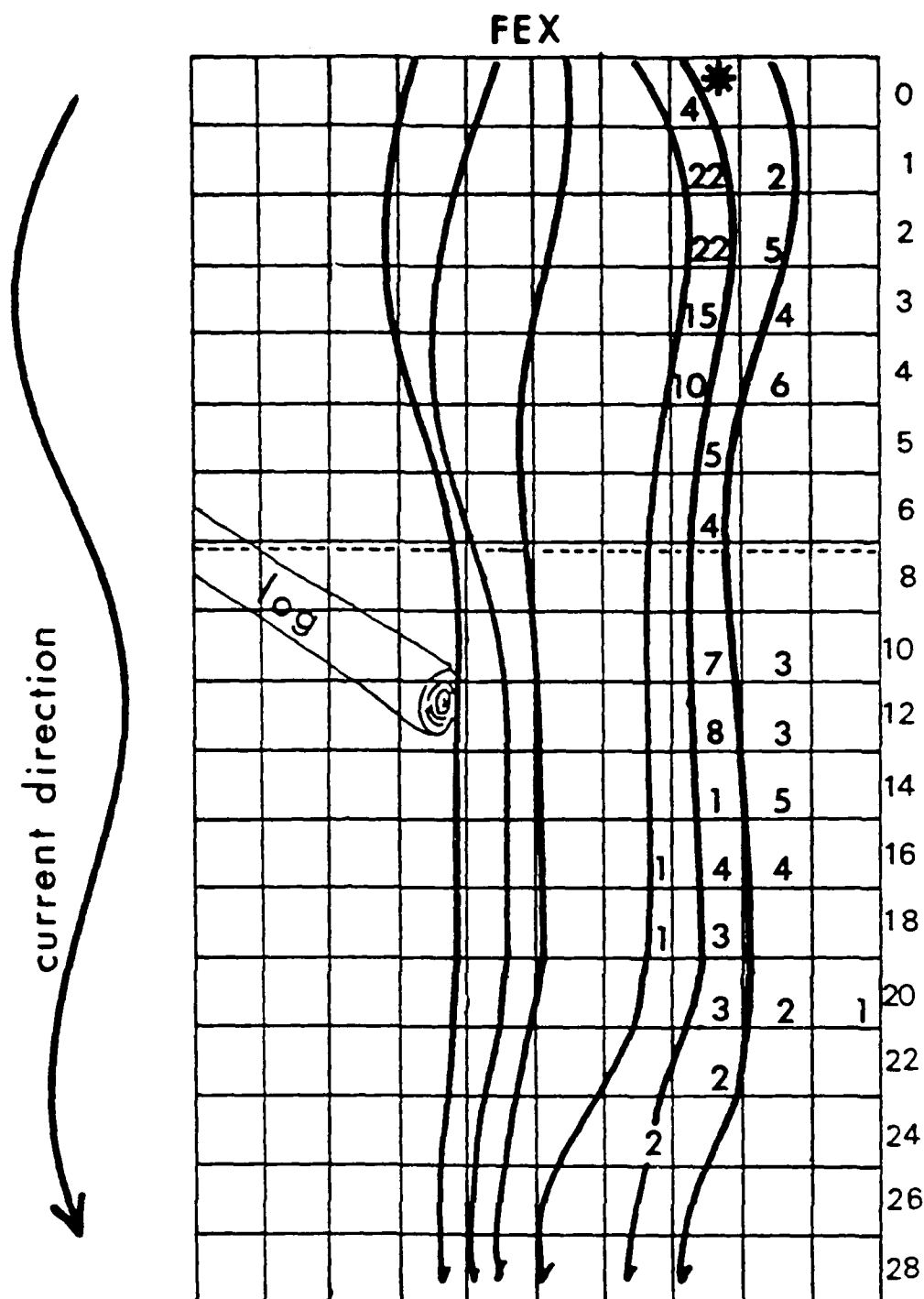


FIGURE 5.1. Mark-recapture site at FEX. Curved lines depict flow patterns. Asterisk represents release site. Values are numbers recaptured 24 hours after release, (Grids are one m^2 to dashed line; thereafter, are two by one meters in area.)

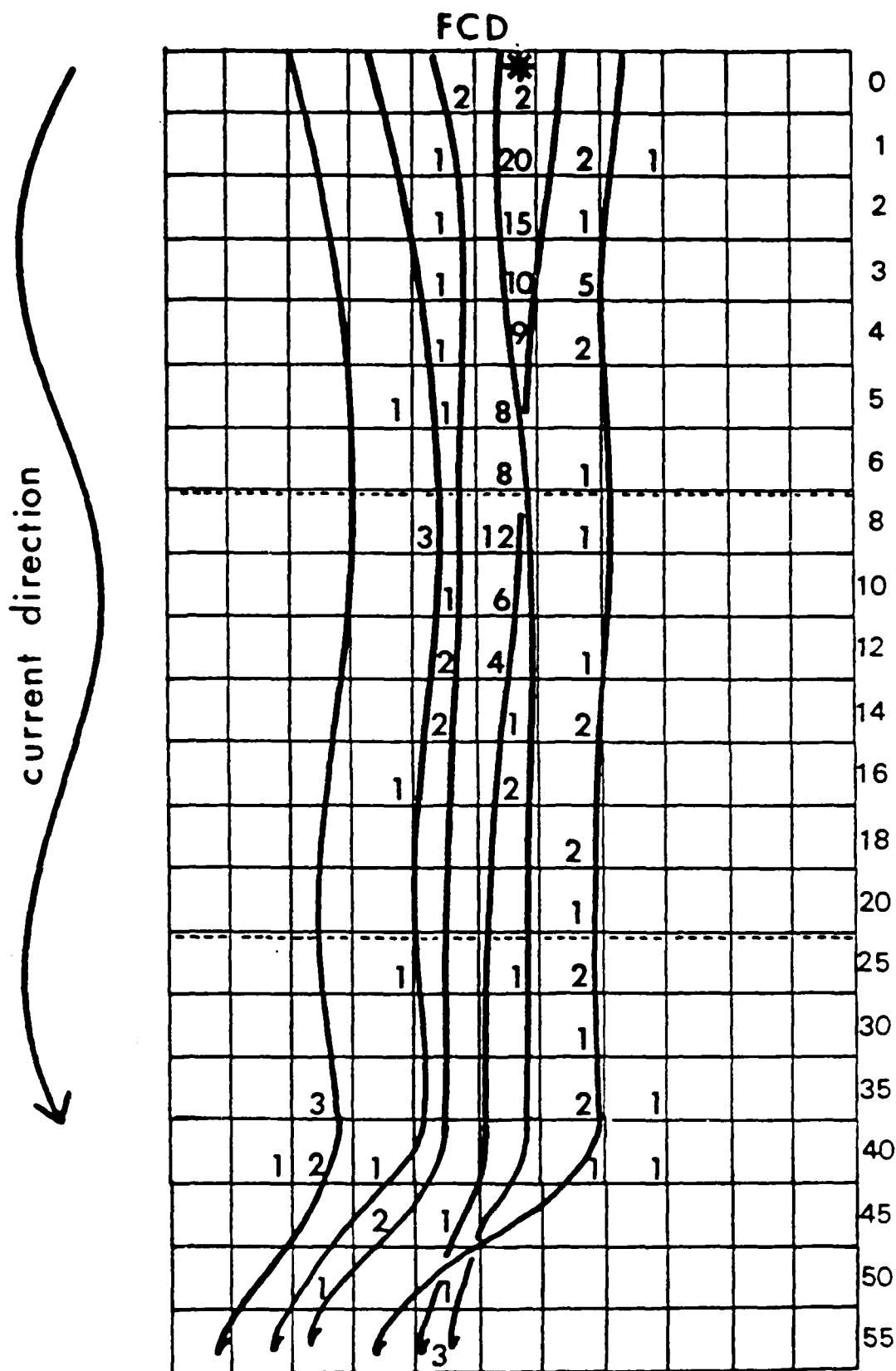


FIGURE 5.2. Mark-recapture site at FCD. Curved lines depict flow patterns. Asterisk: release site. Values: numbers recaptured 24 hr after release, July 1, 1986. (Grid increment: 1-6m downstream, 1m^2 , 8-20m downstream, $2 \times 1\text{m}$; 20-55m downstream, $5 \times 1\text{m}$.)

Twenty-four hours after the initial release, the study area was kickscreen sampled in one meter square areas. A border of at least two meters square were kickscreened upstream, downstream, and along with widths beyond where marked animals were found. After the area had been sampled, marked animals and some of the unmarked animals were painted with another color of Testors paint until at least 300 were marked for the second 24 hr data set. Any animals recaptured 24 hr later that had only the color for the first 24 hr study had been in the stream 48 hr after release. In a second series (late July through early August) no intervening disturbance via kickscreening occurred for either the 24 hr or 48 hr recapture series. The 72 hr recapture series had one kickscreening disturbance (48 hr after the animals had been released). Thus, the two mark-release series could also be used to study the effect of kickscreening on relocation of marked animals that had been in the stream 48 and 72 hr prior to recapture.

The first recapture series occurred between June 25 and 26 at FEX and between July 1 and 2 at FCD. The second series occurred between July 26 and 29 at FEX and between August 5 and 7 at FCD. Population estimates, based on the first 24 hr data at each site were estimated by counting marked and unmarked animals in square meters where marked animals were recovered (Lincoln Index Method after Southwood, 1966). Maximum distances travelled, median distances, and geometric mean distances as well as lateral movements were determined for all recapture dates.

Results

Physical Differences Between FEX and FCD.-- Mean velocities were not significantly lower at FEX than at FCD (FEX: 30.8 cm/sec., FCD: 36.8 cm/sec., $t = -1.237$, d.f. = 34, $p = 0.112$). Mean water depths were not significantly different (FEX = 22 cm, FCD = 21 cm.; $t = .473$, d.f. = 175, $p = 0.315$). The maximum width at FEX was narrower than at FCD (10.6 m vs. 11.7 m). The riffle area at FEX was shorter than at FCD; at FEX it was 25 m and at FCD it was approximately 58 m. In spite of some physical differences between the two sites, mark-recapture results were similar.

Mark-Recapture Results.-- Naiads of O. colubrinus were rather sessile. The net movement direction was downstream. Lateral movements tended to be associated with the flow patterns at each site. Figures 5.1 and 5.2 show the current flow pattern and the numbers of marked animals found in each quadrat after the first 24 hr recapture at each site. Not only was the pattern of recovery similar to flow patterns, but the distances travelled downstream were relatively short. Table 5.1 shows that the maximum distance travelled by marked animals was greater at FCD than at FEX ($t = 9.20$, d.f. = 10). This was also true for the geometric mean

values ($t = 3.01$) and for the median values ($t = 2.14$). The percent of marked animals recaptured away from the release meter column (viewed facing upstream) was higher on the right side than on the left side ($t = 4.05$). This correlates with the direction of flows seen in Figure 5.1. There was no difference between the left and right sides at FCD ($t = 1.61$), probably because the current flow (Fig. 5.2) did not curve toward either bank until 20 m downstream from the release site. There were no differences in the percent found downstream in the release column at either site ($t = 0.48$).

TABLE 5.1

Distances and Directions Travelled by O. colubrinus
at FEX and FCD after 24, 48 and 72 Hours

A. F E X

TIME	LENGTH (meters)			WIDTH		
	MAX.DIST.	MEDIAN	GEO.MEAN	%LEFT	%CTR	%RIGHT
24 hr						
25/VI	27	3	5.40	2.68	73.83	23.49
26/VI	26	2	5.46	8.94	65.04	26.02
29/VII	31	2	2.34	4.93	25.35	69.72
48 hr						
26/VI*	26	7	8.86	2.86	74.29	22.86
31/VII	34	3	6.04	2.16	48.92	48.92
72 hr						
31/VII*	34	6.5	10.36	18.18	24.24	57.58

B. F C D

24 hr						
1/VII	48	6	10.71	19.75	62.42	17.83
2/VII	49	6	10.66	14.29	60.71	25.00
5/VIII	52	3	8.13	20.20	53.69	26.11
48 hr						
2/VII*	44	11	15.49	36.92	35.38	27.69
7/VIII	55	17	19.32	18.18	42.42	39.39
72 hr						
7/VIII*	51	24	24.40	20.83	25.00	54.17

* = One kickscreen sampling between release and recapture.

The marked animals at FCD required more labor to recapture, as they were found both farther downstream and

across more stream widths. Table 5.2 presents an index of difficulty in recapturing animals; i.e., the area that was necessary to recapture one percent of the total marked animals recaptured. The table also gives the total number of square meters sampled.

TABLE 5.2
Index of Difficulty in Recapturing Animals
(Square Meters to Obtain 1% of Total % Return)

SITE	24 hrs	48 hrs	72 hrs.	No. Meters Sampled
FEX	2.93 2.96 2.76	8.46* 3.51	6:15*	128, 97, 131 126, 161 132
FCD	3.97 4.86 4.77	5.25* 8.82	7.36*	198, 216, 241 227, 290 239

* = One kickscreen sampling between release and recapture.

Significant precipitation fell during the course of the last recapture series at FCD (August 5, 6). Although the depth change (August 4: 31.2cm, August 11: 40.7cm) did not appreciably affect our recapture success, it appeared to result in an increased distance downstream that the naiads travelled. This was especially true for the 48 hr recapture. The level of difficulty in recapturing animals (8.82 square meters) and the number of quadrats needed to be sampled (290) were the highest for all the series. Table 5.1 also shows that the median and geometric mean distance travelled was the highest for animals recaptured the 7th of August at FCD (48 and 72 hrs).

Table 5.3 presents percent recapture success as well as population estimates.

TABLE 5.3
Percent Recapture Success and Population Estimates for
Ophiogomphus colubrinus Naiads at FEX and FCD

SITE	PERCENT RECOVERY SUCCESS			POPULATION ESTIMATE (No. Animals/Sq. Meter)
	24 hrs	48 hrs	72 hrs	
FEX	43.70 42.51 47.81	11.46* 45.87	21.29*	$341/149 = x/625$ = 39.7 36 sq.m
FCD	49.84 46.67 50.12	41.14* 32.89	32.76*	$405/203 = x/1047$ = 37.3 56 sq.m

* = One kickscreen sampling between mark and recapture.

The cumulative percent return of recaptured animals from the zero release point to the most downstream location of recapture was similar between FEX and FCD after 24 hrs. (Marked animals were never recovered upstream from the release site.) The only difference was that animals tended to move farther downstream at FCD than at FEX (Fig. 5.3). When, however, the sites had been kickscreened between any recapture, the pattern differed. Figure 5.4A shows cumulative percent recovery going downstream after 48 hours at FEX and FCD when the sites had experienced being kickscreened prior to the 48 hr recovery (to recover the animals that had been marked the previous day -- 24 hr recovery period). The pattern was not smooth; i.e., it was not an arithmetically descending curve. Rather, the ascending and descending zig-zag pattern shows that non-captured animals were displaced as a function of substrata disturbance.

Marked animals were also allowed to remain undisturbed for 48 hrs at each site before recapture (Fig. 5.4B). The pattern for cumulative percent recovery was more similar to the pattern after 24 hrs without intervening disturbance than it was to the pattern after 48 hrs with intervening disturbance. However, the curve was not as smoothly descending and the animals moved longer distances after 48 hrs than after 24 hrs (see Table 5.1). This is what one would expect for rather sessile animals that can float in the current once they are released or are dislodged naturally from the substrata. Figure 5.5 shows a similar pattern found in Figure 5.4B -- the only difference between the two figures is that one (5.4B) shows results after 48 hrs with intervening disturbance and the other one (5.5) shows results after 72 hrs with intervening disturbance.

Spearman-Rank correlations for cumulative percent recaptures were performed to compare differences between recaptures within sites (Table 5.4) and between sites (Table 5.5).

TABLE 5.4

Spearman-Rank Correlations for Cumulative Percent Recaptures

A. FEX SITE

Time	Meters Downstream	24hr (1)	24hr (2)	24hr (3)	48hr (1)	48hr (2)
24hr(1)	-.97	1.00				
24hr(2)	-.89	.82	1.00			
24hr(3)	-.86	.79	.80	1.00		
48hr(1)	-.80	.81	.65	.71	1.00	
48hr(2)	-.88	.86	.75	.77	.84	1.00
72hr(1)	-.67	.70	.64	.56	.63	.50
Critical value (2-tail, .05) = + or - .50						

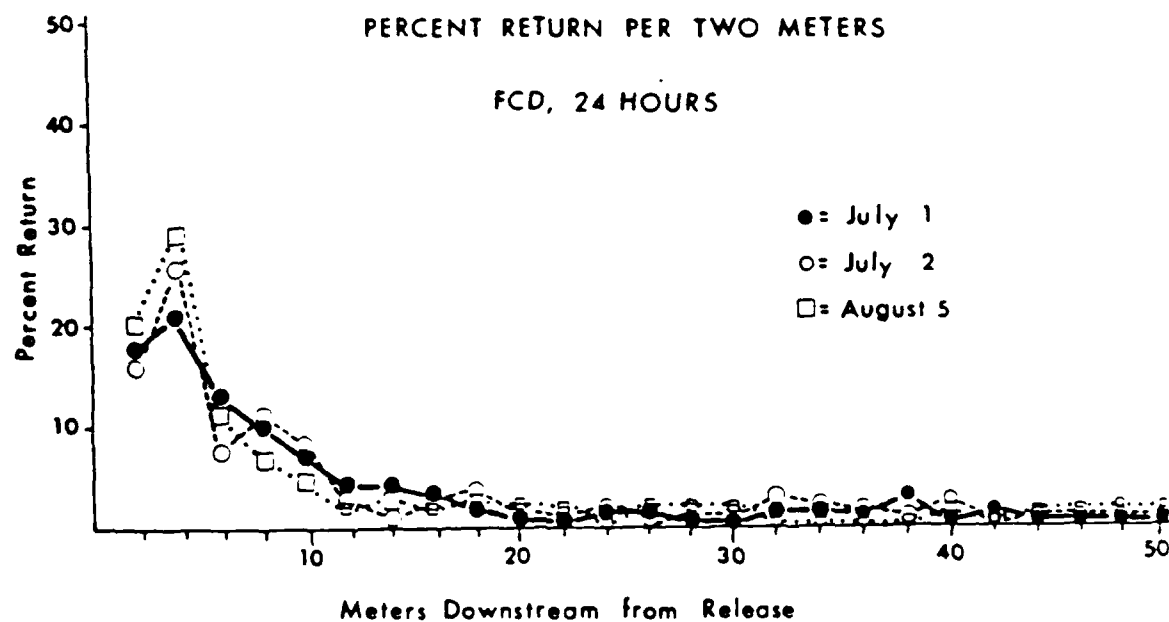
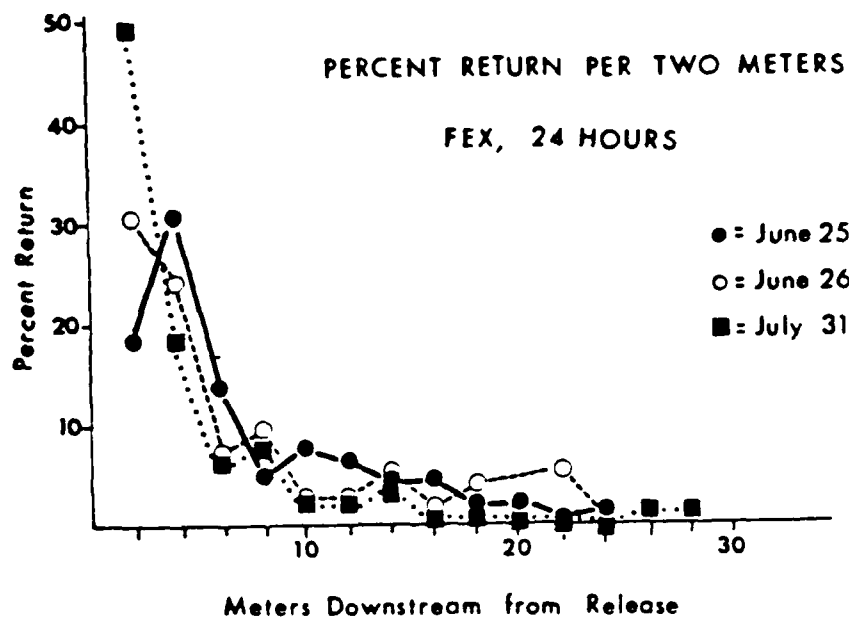


FIGURE 5.3. Comparisons among three 24hr recapture periods at each site (FEX, FCD). Percent recaptured at two meter intervals.

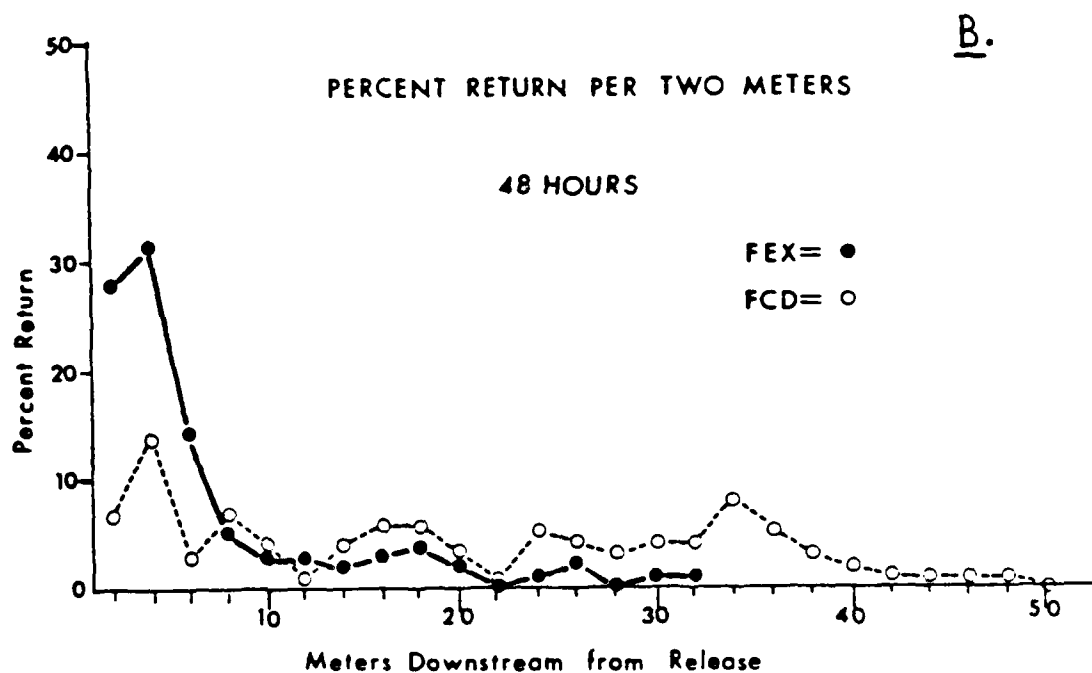
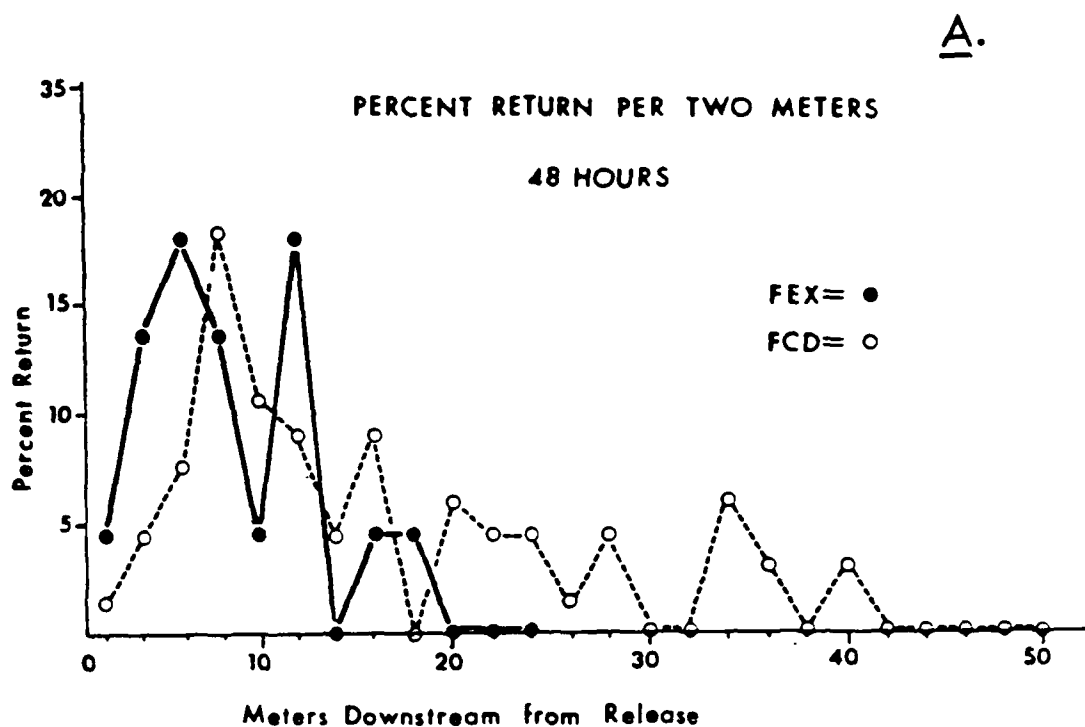


FIGURE 5.4 A. Percent animals recaptured at two meter intervals at FEX and FCD, where the area was kickscreened between release and recapture period (for the 24 hr study).

FIGURE 5.4 B. Percent animals recaptured at two meter intervals at FEX and FCD, where the area was not kickscreened prior to capture.

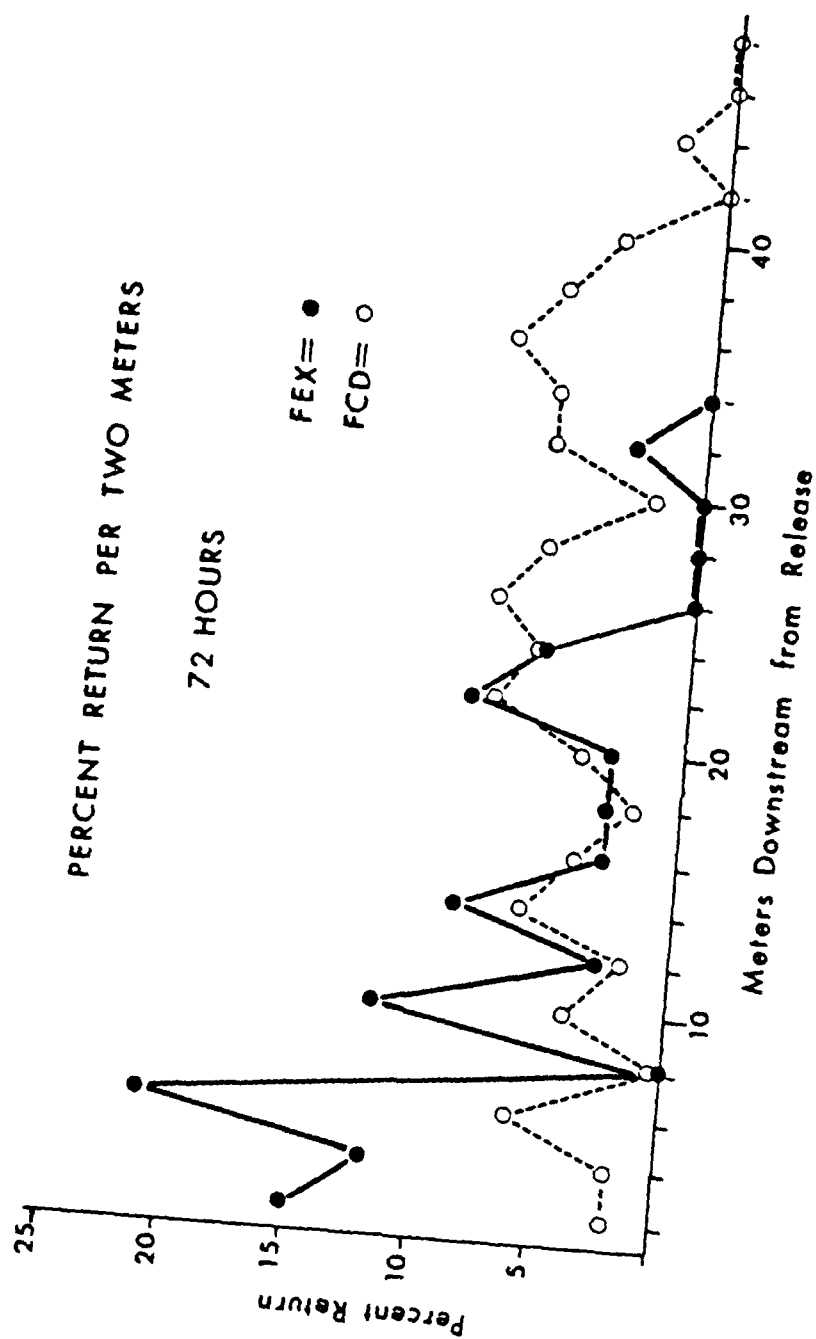


FIGURE 5.5. Percent of total animals recaptured per each two meter interval after 72 hours. The area was kickscreened prior to the 72 hr recovery and after the release of the animals.

TABLE 5.4 continued

B. FCD SITE

Time	Meters Downstream	24hr (1)	24hr (2)	24hr (3)	48hr (1)	48hr (2)
24hr(1)	-.77	1.00				
24hr(2)	-.78	.73	1.00			
24hr(3)	-.73	.75	.65	1.00		
48hr(1)	-.69	.50	.52	.44	1.00	
48hr(2)	-.59	.55	.72	.45	.36	1.00
72hr(1)	-.16	.04	.07	-.28	.26	.23
Critical value (2-tail, .05) = + or - .40						

The Spearman-Rank correlations show that there are significant positive correlations between recapture values for all recapture intervals except between the second and the third 48 hr period and for the 72 hr period as compared with all other time periods at FCD. It was during the 48 and 72 hr periods that heavy rains fell.

TABLE 5.5
Spearman-Rank Correlations for Cumulative Percent Recaptures
Between FEX and FCD After 24, 48 and 72 Hours
(From Release Point to 32 Meters Downstream)

Time	Meters Downstream	FEX24 (1)	FEX24 (2)	FEX24 (3)	FEX48 (1)	FEX48 (2)	FEX72 (1)
FCD24(1)	-.91	.90	.79	.87	.80	.86	.63
FCD24(2)	-.74	.74	.62	.71	.79	.75	.46
FCD24(3)	-.91	.92	.76	.79	.82	.77	.57
FCD48(1)	-.51	.53	.29	.32	.53	.29	.16
FCD48(2)	-.38	.34	.35	.35	.24	.57	.03
FCD72(1)	.49	-.49	-.41	-.36	-.59	-.62	.10
Critical value (2-tail, .05) = + or - .50							

There were high correlations between the sites with respect to the 24hr cumulative percent recaptures (range: 0.62 to 0.91). The correlations between the sites with respect to the 48 hr cumulative percent recaptures were lower. Significance was found only between the first 48 hr series and between the second 48 hr series for the two sites. The 72 hr period showed no correlation between the two sites (0.10). Further, it was only for the 72 hr period at FCD that there was a positive correlation between percent recaptured and increasing distance from the release site and negative correlations between the 72 hr period at FCD and the 24 and 48 hr recaptures at FEX. One or two factors

could account for these differences -- a kickscreen sampling between the final recapture and/or an accumulation of three days of rain.

Comparisons with 1984 and 1985 Data

Percent recapture success was higher in 1986 than in 1985 and 1984. This may be owing to better methods of sampling. In 1986, we placed a 1.5 m wide handscreen behind the areas we were sampling; thus, we caught a few of the marked insects that did not enter the screens directly downstream of the square meters we were sampling. We estimate about a 3 - 5% increase in recapture success by this new method. It will be continued in future years.

The direction of movement of the animals remained the same over the three years -- downstream. The geometric mean distances travelled were similar for the two sites; however, the maximum distances travelled were longer in 1986 than in 1985 and 1984 at the two sites. Once again, as for 1985, rains at FCD appeared to affect geometric mean distances and maximum distances travelled by the animals. Once a mark-recapture series is initiated, it will take two weeks to complete the series; thus, heavy rains may occur in the future and they may affect the results. Since rainfall and discharge are monitored, we will continue to be able to correlate changes in weather with changes in results.

Population estimates were lower in 1986 than in 1985. However, as kickscreening of the areas can affect population estimates, only the first sampling data can be used with confidence for the estimates. Therefore, statistical comparisons between the years were not made. As the major question asked in this element is: "What are movement patterns for this insect predator?", the problem is not of great concern.

Discussion

As time increased (number of hours that the insects were in the stream), distance travelled increased. The insects appear to be rather passive; not only is the net longitudinal direction downstream, but the lateral direction is related to the flow patterns at each of the sites.

Comparisons for the 24 hour mark-recaptures showed that the two sites did not statistically differ. If, however, kickscreening occurred between release and final recapture, recapture success and locations of animals were affected. Thus, in 1987, we will not kickscreen between the 48 and 72 hour periods. This should result in having the animals move in similar rates as for the 24 hour period. However, the animals are expected to increase distances travelled with increasing time spent in the stream.

If ELF effects alter movements of these animals such that they travel significantly longer distances, change their direction of movement, or remain even more sessile, we should be able to detect those differences, as data collected without the influence of ELF are consistent and predictable. If ELF affects population numbers, detection will not be possible using data from this element. The substrate studies would be better used than the mark-recapture studies. If sufficient labor were available, we would sample square meter areas, going into the substrate at least 10 cm and directly counting the number of individuals found in at least 10 samples per site. This is not possible at the present time.

Summary

Naiads of O. colubrinus travelled in a downstream direction for short distances over time at FEX and FCD. Their lateral movements were related to flow patterns at each of the sites. Percent recapture success was sufficiently high (usually over 40%) to make us rather confident that we are monitoring actual movement patterns of this predator. The only difference between FEX and FCD with respect to movement patterns was that animals tended to move farther at FCD. This is likely related to the higher mean velocities at that site. Owing to the numerical dominance, markability and sessile behavior of these animals, they are appropriate for movement pattern studies. Further, the repeatability of the results indicates that if effects of ELF alters movements of these rather sessile animals, we will be able to detect those changes.

Literature Cited

Southwood, T. R. E., 1966. Ecological Methods. Methuen & Co., Ltd., London, 391 pp.

Element 6 - Leaf Litter Processing

Changes from the Original Synopsis - None.

Objectives

1) To monitor fresh and dried leaf processing rates during the fall-winter of 1985-86; 2) to monitor processing rates of fresh leaves during the summer of 1986; 3) to monitor fresh and autumn abscised leaf processing rates during the fall-winter of 1986-87; 4) to monitor colonization patterns of insects on all experimental leaves, and, 4) to compare 1985-1986 results with those from prior years.

Processing rates of leaves incorporate the functional responses of fungi, bacteria, other micro-organisms and certain aquatic insects as they use leaves as both a nutritive and substrata resource. If E.L.F. alters any of those communities, differences in processing rates of the leaves themselves should be expected. As data thus far show that fresh summer and autumn senescent leaves have predictable and consistent leaf processing rates (Stout, et al. 1985), rate changes as a function of E.L.F. should be detected.

Insects colonize leaves in a general sequential pattern: After conditioning by bacteria and fungi, insect functional feeding groups such as shredders, scrapers, collector-gatherers, filter-feeders and predators arrive in sequence. If any of those sequence "groups" are missing as a function of E.L.F., not only the sequence pattern, but relative abundances and growth rates of insects on leaves over time can be altered. Changes would be detected via changes in numbers and/or biomasses of functional feeding groups as well as size class structural alterations. As shredders are often the first insects to arrive, it is expected that they may be the most susceptible to prior deviations in the micro-organism community. Thus, particular attention to shredders is given in the event this is the case. A chironomid shredder, Brillia flavifrons, a mayfly collector-gatherer Ephemerella invaria, and a stonefly predator, Isoperla transmarina were selected as target species, as they are common on leafpacks and show consistent size classes changes over time.

1985-1986 Data

Materials and Methods

On September 17, 1985, freshly picked Tag Alder (Alnus glutinosa) leaves were put into leaf packs of 10 leaves per pack, weighed, then taken to the Ford River at the FEX and FCD sites and lashed to bricks before placing them in the river. Sufficient numbers of the previous year's autumn leaves were lacking, and therefore, freshly picked leaves were over

dried for 48 hr, weighed and put into 2.20 to 2.40 gm packs before putting them into the river on 17 September. Seven samples per leaf treatment were recovered after 3, 9, 26 and 54 days at both sites. Owing to extreme weather conditions, leaves were recovered from FCD after 107 days and from FEX after 135 days. Leaves were washed over a 60um mesh soil sieve and insects were stored in 70% ethanol. Washed leaves were dried at 60oC for 48 hr and then weighed to the nearest mg.

On June 20, 1986, fresh leaves were collected from a single grove adjacent to the Ford River, returned to the laboratory, weighed (fresh weight) into 5.00 to 5.30 gm leaf packs, and taken to FEX and FCD that day. (Earlier, a regression of fresh weight to dry weight was made from a total of 200 leaves. The r^2 was 0.98; thus, dry leaf estimates based on known fresh weight values were possible.) Six replicates were recovered after 3, 10, 29, 45, and 56 days at the two sites. The recovered samples were treated in the same manner as the previous fall's studies.

On September 10, 1986, fresh leaves were collected from a grove adjacent to the Ford River, weighed (fresh weight) into 5.20 to 5.30 gm leafpacks and taken to FEX and FCD that day. Seven replicates per site were collected after 3, 9, 27, 45, 56 and 86 days. Autumn abscised leaves were collected daily from parachutes placed under tag alder trees. After drying them for 48 hr at 60oC, leafpacks ranging in dry weight from 2.30 to 2.40 gm were lashed to bricks and placed at FEX and FCD sites September 19. Seven replicates per site were collected after 3, 9, 27, 45, 56 and 86 days.

Leaf processing rates ($-k$) were computed after Petersen and Cummins, 1975. Mean dry \bar{w} weights rather than percent dry weight remaining were used so that comparisons with data from prior years could be made. Two-Way ANOVA tests (site versus treatment; changes in $-k$ over time) were run after tests for homogeneity of variances. After linear regressions were run to determine $-k$ values, t-tests were performed to determine if differences in slopes for the regressions existed.

The insect taxa from the leaves were identified. Insects were then measured to the nearest mm for later computation of biomass values. Taxon diversity (H'), richness (S) and evenness (J') were computed for each replicate. Number of individuals and total biomass for each replicate were also computed. For select taxa, percent numerical dominance and/or mean biomass per individual were determined. Finally, total biomass values for functional feeding group categories (including a special category, Chironomidae) were computed (after Merritt and Cummins, 1984). Coefficient of variation (C.V.) values for each estimated parameter from each set of replicates were computed. A power test was used to determine if sufficient

replicates had been collected to have, 95% of the time, confidence that the mean varied no more than + 40% with an alpha of .05. (Seven replicates were sufficient if the parameter had a C.V. value of 20% or less.) If values for any parameter were not normally distributed, they were transformed prior to analysis (e.g., percent data).

Results and Discussion

Leaf Processing Rates.-- Figure 6.1A shows that green leaves whether fresh or dried were processed significantly faster at FEX than at FCD during the fall-winter study of 1985-86: A two-tailed t-test for differences between slopes for fresh leaves at FEX and FCD was 1.709 (d.f. = 54, $p = 0.047$) and for dried leaves, $t = 2.058$ (d.f. = 54, $p = 0.022$). However, treatment comparisons within sites showed no significant difference (FEX: $t = 0.839$, d.f. = 54, $p = 0.203$; FCD: $t = 1.054$, d.f. = 54, $p = 0.148$). Data after 54 days' immersion were excluded from analysis as the leaves were not washed sufficiently after that time.

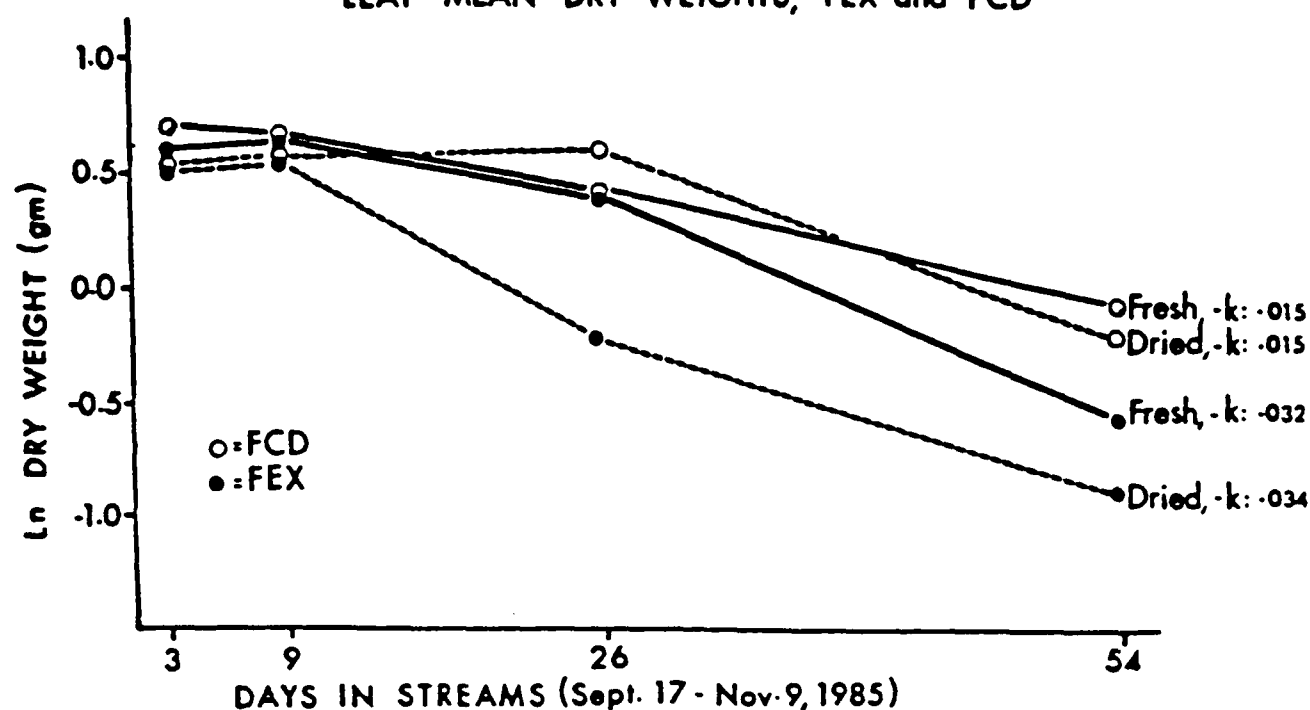
Table 6.1 shows 2-Way ANOVA values for tests of site versus treatment differences for the 1985 fall study for each recovery date. Treatment differences were significant on Day 3 and 9; afterward, site differences were significant (leaves were processed faster at FEX than at FCD).

TABLE 6.1
Comparisons between Fresh and Oven-dried Leaf Losses at FEX and FCD, Fall of 1985. Two-Way ANOVA for Site Versus Treatment

Days in Stream	Source	d.f.	MSS	F-ratio	Prob.
3	site	1	.030	1.868	.184
	treatment	1	.183	11.414	.002***
	interaction	1	.068	4.250	.050*
	error	24	.016		
9	site	1	.0005	.043	.837
	treatment	1	.105	7.776	.010**
	interaction	1	.012	.923	.349
	error	24	.013		
26	site	1	.628	5.802	.024*
	treatment	1	.098	.908	.350
	interaction	1	.800	7.407	.0120**
	error	24	.108		
54	site	1	6.303	13.361	.001***
	treatment	1	.312	.661	.424
	interaction	1	.040	.085	.774
	error	24	.072		

A

LEAF MEAN DRY WEIGHTS, FEX and FCD



B

FRESH LEAVES, MEAN DRY WEIGHTS

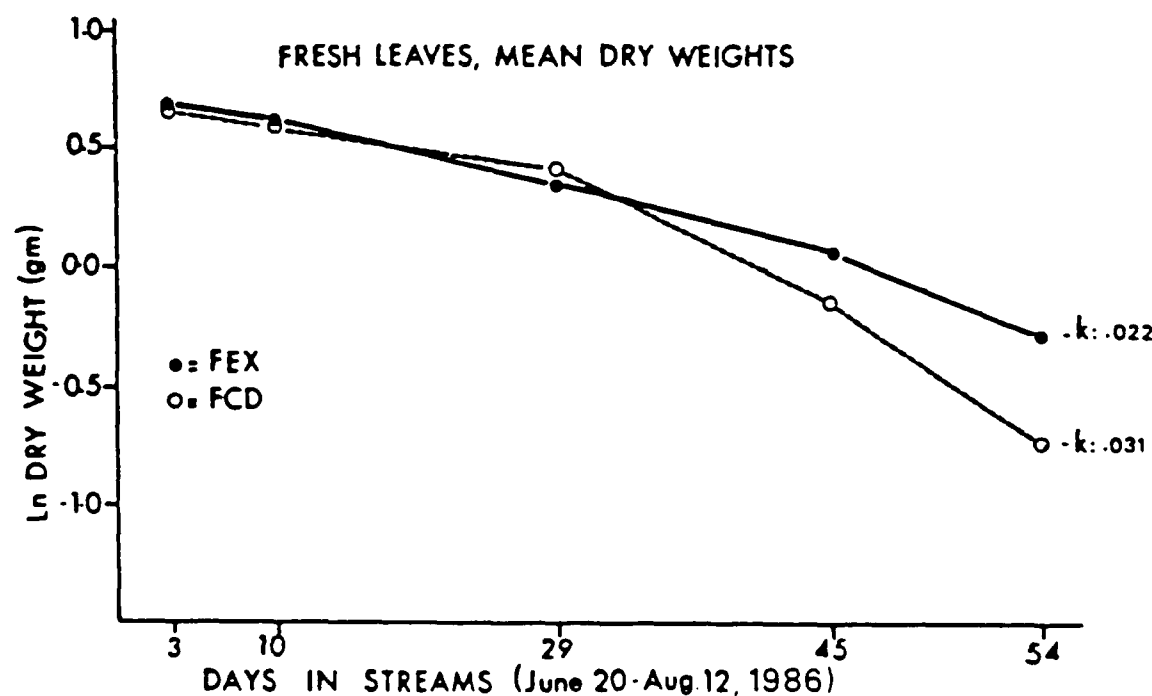


FIGURE 6.1A. Processing rates of fresh and oven-dried leaves at FEX and FCD from September 17 to November 9, 1985.

FIGURE 6.1B. Processing rates of fresh and oven-dried leaves at FEX and FCD from June 20 August 12, 1986. ($-k$ = processing coefficient).

Figure 6.1B shows mean dry weights of fresh leaves from the summer of 1986. There were no differences between sites for processing rates ($t = 0.523$, d.f. = 52, $p = 0.302$). Summer fresh leaf dry weights did not differ significantly from the previous fall's fresh leaf dry weights (FEX: $t = 0.699$, d.f. = 44, $p = 0.244$; FCD: $t = 1.443$, d.f. = 44, $p = 0.078$). Day 45 for the summer 1986 study was excluded from analysis, as comparable data were lacking for the 1985 fall study.

Analysis of the fall-winter of 1986-1987 study for fresh versus autumn abscised leaves will be presented in the 1987 Annual Report.

Insects Colonizing Leafpacks.--Structural Community Parameters: Taxon diversity values decreased over time irrespective of site or treatment during the fall of 1985 study (Fig. 6.2A). Two-Way ANOVA tests for each collection date showed that after an initial site difference (FEX was higher than FCD) there were no differences between fresh and oven-dried leaves (Table 6.2). Coefficient of variation (CV) values were all well below 20% until Day 54. The maximum CV value after that day never exceeded 35%.

TABLE 6.2
Comparison of Taxon Diversity Values for Insects on
Fresh and Oven-Dried Leaves at FEX and FCD
Two-Way ANOVA for Site Versus Treatment Differences

Days in Stream	Source	d.f.	MSS	F-ratio	Prob.
3	site	1	1.223	14.063	.001***
	treatment	1	.0005	.002	.938
	interaction	1	.043	.494	.488
	error	24	.087		
9	site	1	.184	1.604	.218
	treatment	1	.083	.728	.402
	interaction	1	.002	.017	.900
	error	24	.115		
26	site	1	.607	3.419	.077
	treatment	1	.554	3.124	.090
	interaction	1	.466	2.633	.118
	error	24	.177		
54	site	1	.027	.083	.775
	treatment	1	.018	.056	.315
	interaction	1	.029	.091	.764
	error	24	.319		

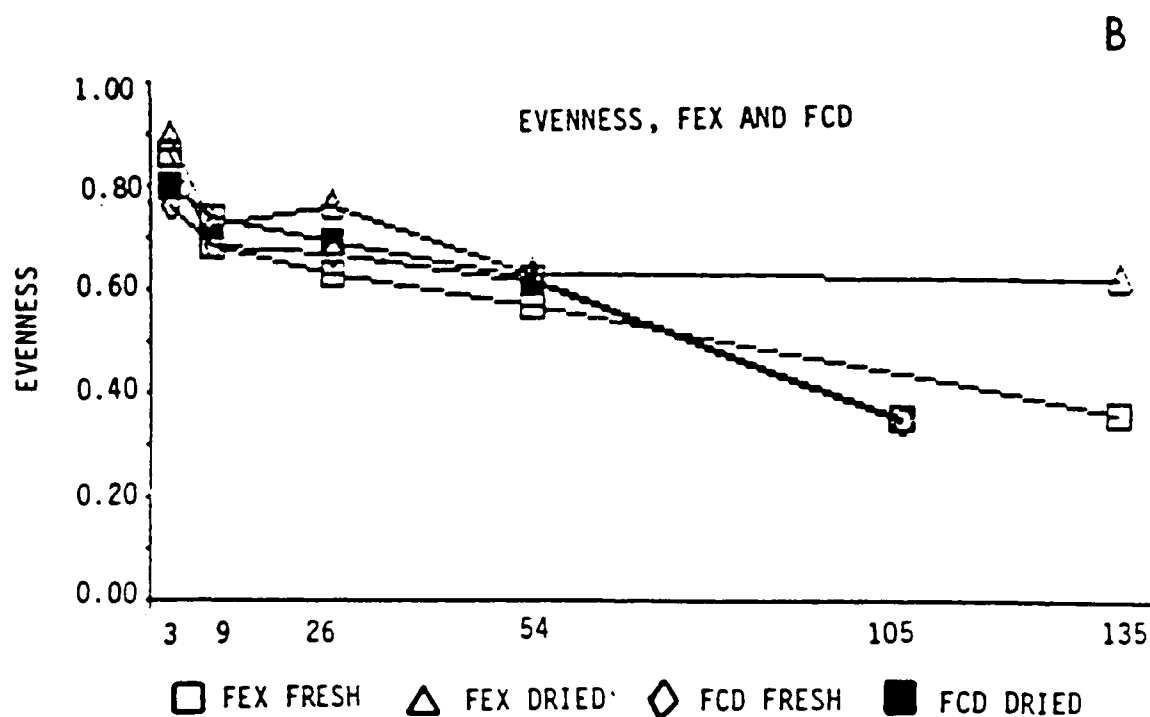
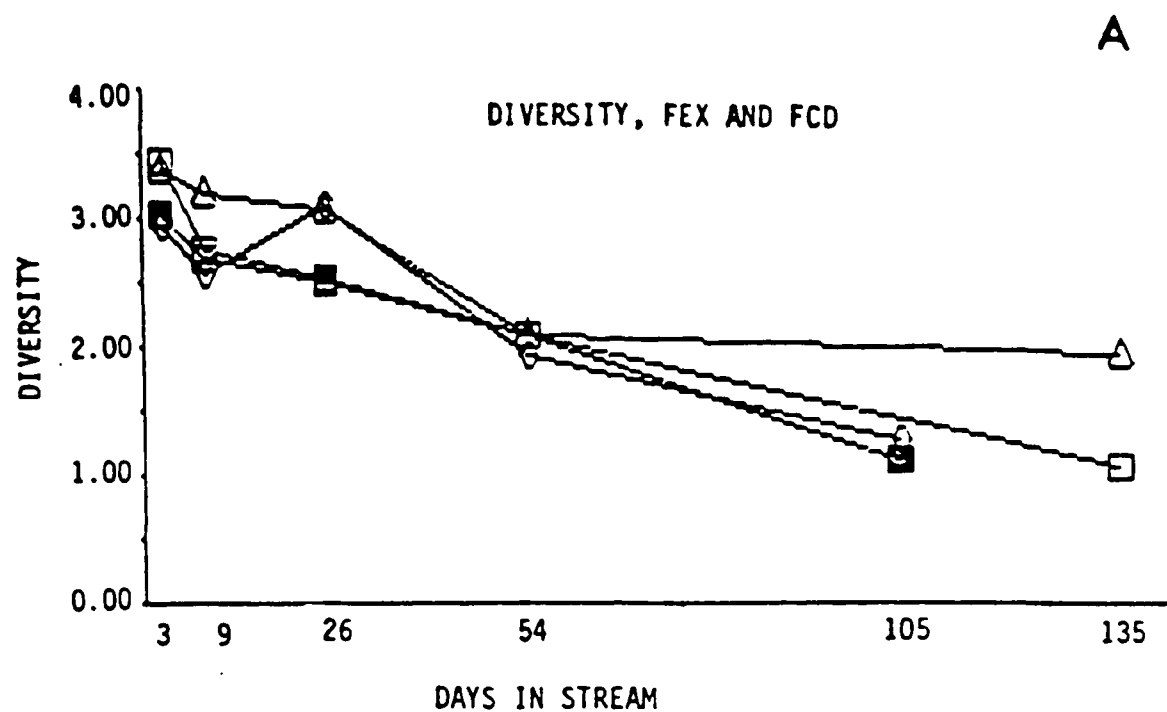


FIGURE 6.2A Taxon diversity of aquatic insects on fresh and oven-dried leaves at FEX and FCD from September 17, 1985 to January 31, 1986.

6.2B Taxon evenness (J') for aquatic insects on fresh and oven-dried leaves at FEX and FCD from September 17, 1985 to January 31, 1986.

Evenness values (J') lowered with time (Fig. 6.2B). Only on Day 3 were there site differences (Table 6.3). At that time, both fresh and autumn leaf J' values were higher at FEX. At Day 26, J' values were higher on dried than on fresh leaves at both sites. C.V. values were above 20% only after Day 54. Thus, for the most part, sufficient samples had been taken to reduce the probability of a Type II error.

TABLE 6.3
Comparisons Among Evenness (J') Values for Insects
for Insects on Fresh and Dried Leaves at FEX and FCD
Two-Way ANOVA for Site Versus Treatment Differences
(Arcsine Transformation of Data)

Days in Stream	Source	d.f.	MSS	F-ratio	Prob.
3	site	1	.070	26.643	.00003***
	treatment	1	.008	3.229	.085
	interaction	1	.00008	.027	.861
	error	24	.003		
9	site	1	.001	.156	.696
	treatment	1	.014	2.144	.156
	interaction	1	.0003	.043	.842
	error	24	.007		
26	site	1	.003	.161	.692
	treatment	1	.045	6.658	.016*
	interaction	1	.022	3.143	.083
	error	24	.007		
54	site	1	.003	.188	.669
	treatment	1	.008	.565	.460
	interaction	1	.003	.214	.640
	error	24	.014		

At FEX, taxon richness (S) values for fresh and dried leaves generally increased through Day 26 and then diminished afterward. At FCD, the values tended to decrease over time (Fig. 6.3A). Between Day 9 and Day 54, taxon richness was higher at FEX than at FCD. For the most part, richness values were higher on both fresh and dried leaves at FEX than at FCD (Table 6.4). C.V. values were below 20% through Day 26; on Day 54, C.V. values were 39% for fresh leaves and 45% for dried leaves at FCD. (Values were below 20% at FEX for that date.)

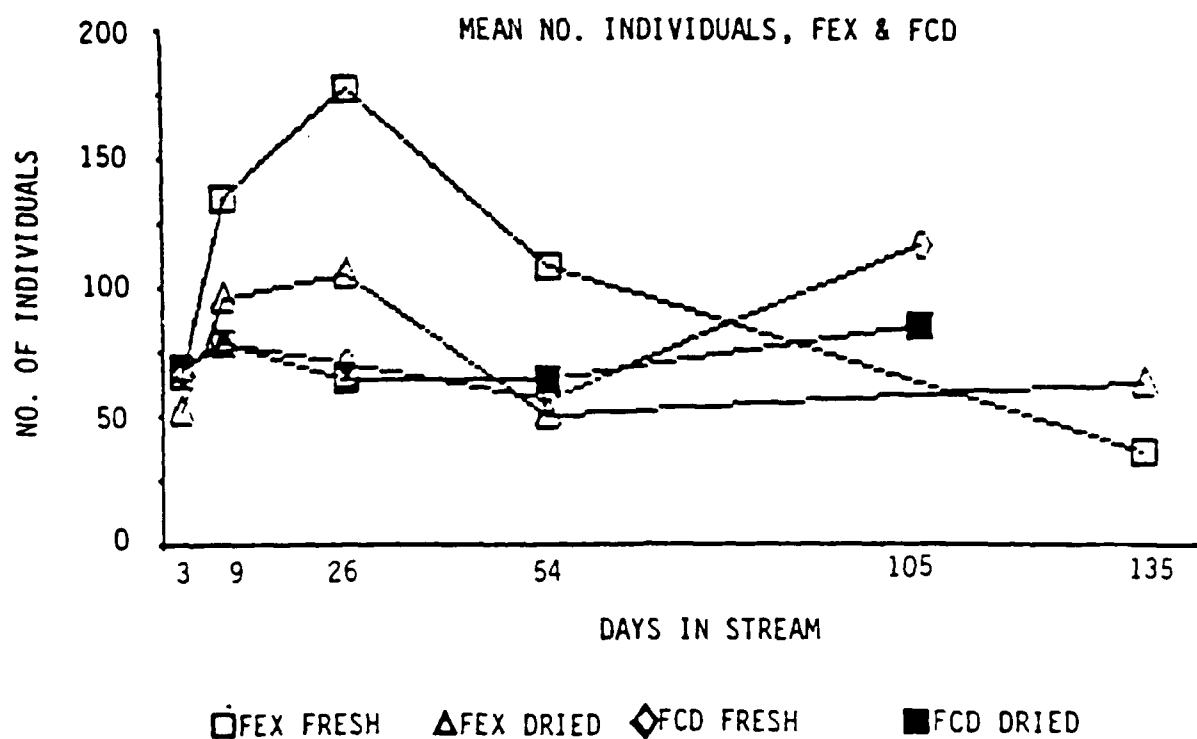
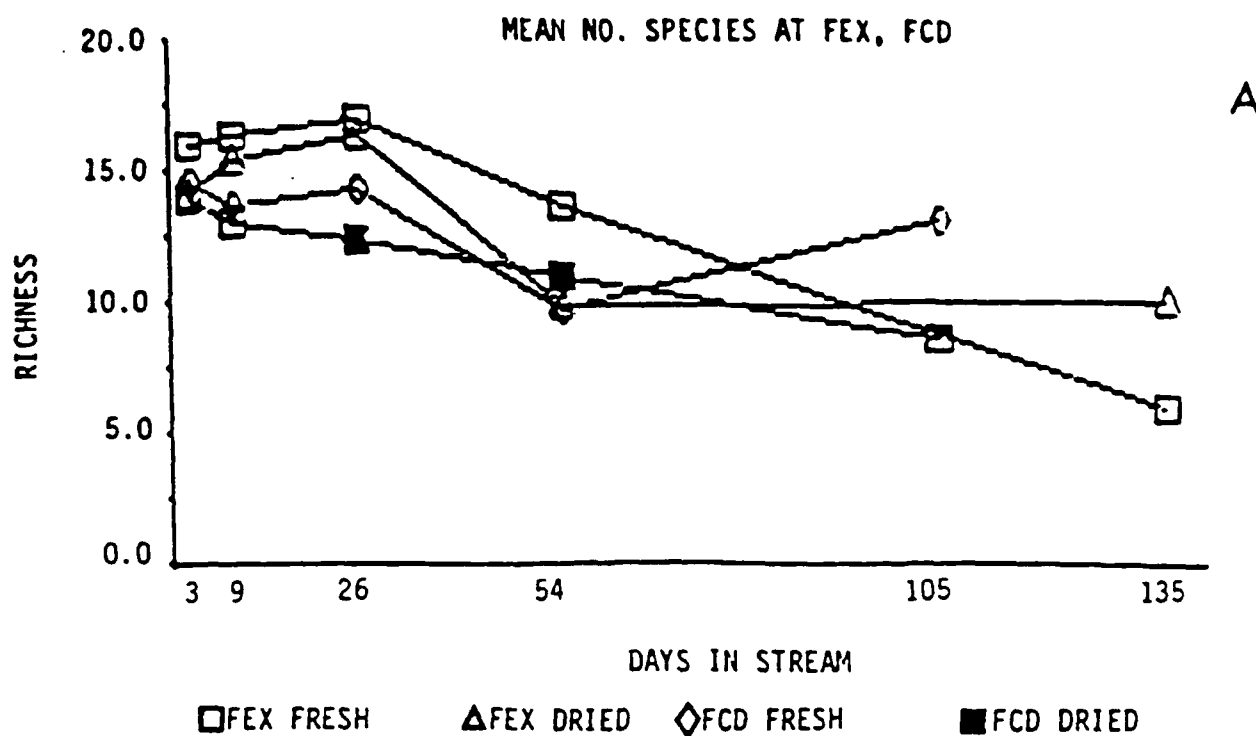


FIGURE 6.3A. Taxon richness for aquatic insects on fresh and oven-dried leafpacks at FEX and FCD from Sept. 17, 1985 to Jan. 31, 1986.

FIGURE 6.3B. Mean number of individuals on fresh and oven-dried leafpacks at FEX and FCD from Sept. 17, 1985 to Jan. 31, 1986.

TABLE 6.4
Comparisons Among Taxon Richness Values (S) for Insects
on Fresh and Autumn Leaves at FEX and FCD
Two-Way ANOVA for Site Versus Treatment Differences

Days in Stream	Source	d.f.	MSS	F-ratio	Prob.
3	site	1	2.286	.389	.539
	treatment	1	14.286	2.429	.132
	interaction	1	5.143	.874	.359
	error	24	5.881		
9	site	1	43.750	4.823	.038*
	treatment	1	2.893	.319	.578
	interaction	1	.321	.035	.852
	error	24	9.071		
26	site	1	66.036	5.020	.035*
	treatment	1	12.893	.980	.332
	interaction	1	6.036	.459	.505
	error	24	13.155		
54	site	1	14.286	1.035	.319
	treatment	1	41.286	2.992	.096
	interaction	1	9.143	.663	.424
	error	24	13.798		

Numbers of individuals peaked at Day 26 (Fig. 6.3B). There were significantly more individuals on Day 9 and 26 for both leaf treatments at the FEX site than at the FCD site (Table 6.5). Treatment differences were not significant at the .05 level. C.V. values were all usually over 20% (up to 78%). Much higher numbers of replicates for this parameter would have to have been taken to have 95% confidence that the mean was \pm 40% of its estimated value at the .05 alpha level.

TABLE 6.5
Comparisons Among Numbers of Individuals on Fresh and Dried
Leaves at FEX and FCD
Two-Way ANOVA for Site Versus Treatment Differences

Days in Stream	Source	d.f.	MSS	F-ratio	Prob.
3	site	1	576.036	1.979	.172
	treatment	1	350.036	1.203	.284
	interaction	1	456.036	1.567	.223
	error	24	291.083		

Table 6.5 continued

Days in Stream	Source	d.f.	MSS	F-ratio	Prob.
9	site	1	9325.750	9.820	.004***
	treatment	1	2740.321	2.886	.102
	interaction	1	2900.893	3.055	.093
	error	24	949.655		
26	site	1	37742.286	12.068	.002***
	treatment	1	10260.571	3.281	.083
	interaction	1	7755.571	2.480	.128
	error	24	3127.512		
54	site	1	2358.893	1.302	.265
	treatment	1	7458.893	4.117	.054
	interaction	1	4500.893	2.484	.128
	error	24	1811.845		

All structural community parameters with respect to both sites (FEX and FCD) and treatment (fresh and oven-dried), tended to decrease over time, with the exception of total number of individuals. The steady decrease in H' and J' can be accounted for by the steady increase in numerical dominance by chironomids over time (Fig. 6.4). Chironomid dominance was not related to site or leaf treatment differences after Day 3 and before Day 105 (Table 6.6).

TABLE 6.6

Comparison of Percent Numerical Dominance (Arcsine Transformation) of Chironomids on Fresh and Oven-Dried Leaves at FEX and FCD
Two-Way ANOVA for Site Versus Treatment Differences

Days in Stream	Source	d.f.	MSS	F-ratio	Prob.
3	site	1	1226.045	48.814	.0000****
	treatment	1	13.908	.554	.464
	interaction	1	2.414	.096	.759
	error	24	25.117		
9	site	1	30.059	.371	.548
	treatment	1	237.578	2.933	.100
	interaction	1	36.531	.451	.508
	error	24	80.992		
26	site	1	9.527	.090	.766
	treatment	1	209.295	1.988	.171
	interaction	1	226.906	2.155	.155
	error	24	105.284		

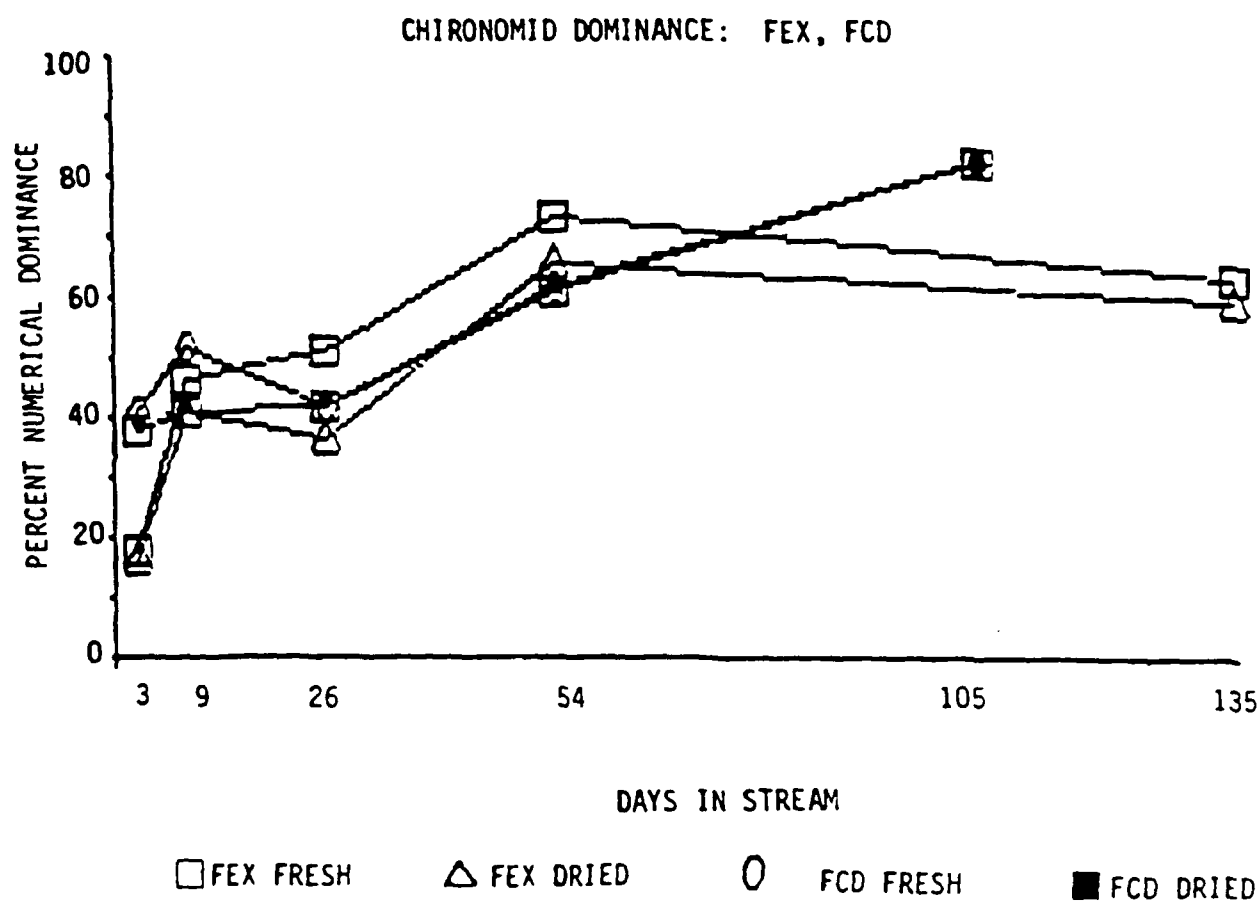


FIGURE 6.4. Numerical percent dominance of chironomids (relative to all other individuals) on fresh and oven-dried leaves at FEX and FCD from September 17, 1985 to January 31, 1986.

Table 6.6 continued

Days In Stream	Source	d.f.	MSS	F-ratio	Prob.
54	site	1	275.397	1.617	.216
	treatment	1	109.757	.645	.430
	interaction	1	32.655	.192	.665
	error	24	170.261		
135(FEX)					
105(FCD)	site	1	1745.515	14.689	.0008****
	treatment	1	.686	.008	.9401
	interaction	1	73.872	.621	.438
	error	24	119.034		

Insect colonization patterns for fresh leaves during the summer of 1986 and during the fall-winter season of 1986 will be described in the 1987 Annual Report.

Functional Community Parameters: Total biomass values (adjusted to leaf biomass) showed a consistent upward trend over time (Fig. 6.5). A 2-Way ANOVA showed site differences (but never treatment differences) after 26 days' immersion (Table 6.7). For Day 26 and 54, both fresh and oven-dried leaves had a higher biomass of insects at FEX than at FCD.

TABLE 6.7
Comparisons of Total Insect Biomass (Adjusted to Leaf Biomass) Between Fresh and Oven-Dried Leaves at FEX and FCD.
Two-Way ANOVA for Site Versus Treatment Differences

Days In Stream	Source	d.f.	MSS	F-ratio	Prob.
3	site	1	.048	.046	.831
	treatment	1	.191	.185	.671
	interaction	1	2.250	2.178	.153
	error	24	1.033		
9	site	1	41.717	2.509	.126
	treatment	1	22.060	1.327	.261
	interaction	1	44.546	2.679	.115
	error	24	16.626		
26	site	1	51.444	12.937	.001***
	treatment	1	3.163	.795	.381
	interaction	1	.854	.215	.647
	error	24	3.976		
54	site	1	194.382	8.054	.01**
	treatment	1	27.490	1.139	.299
	interaction	1	270.265	11.198	.003***
	error	24	24.135		

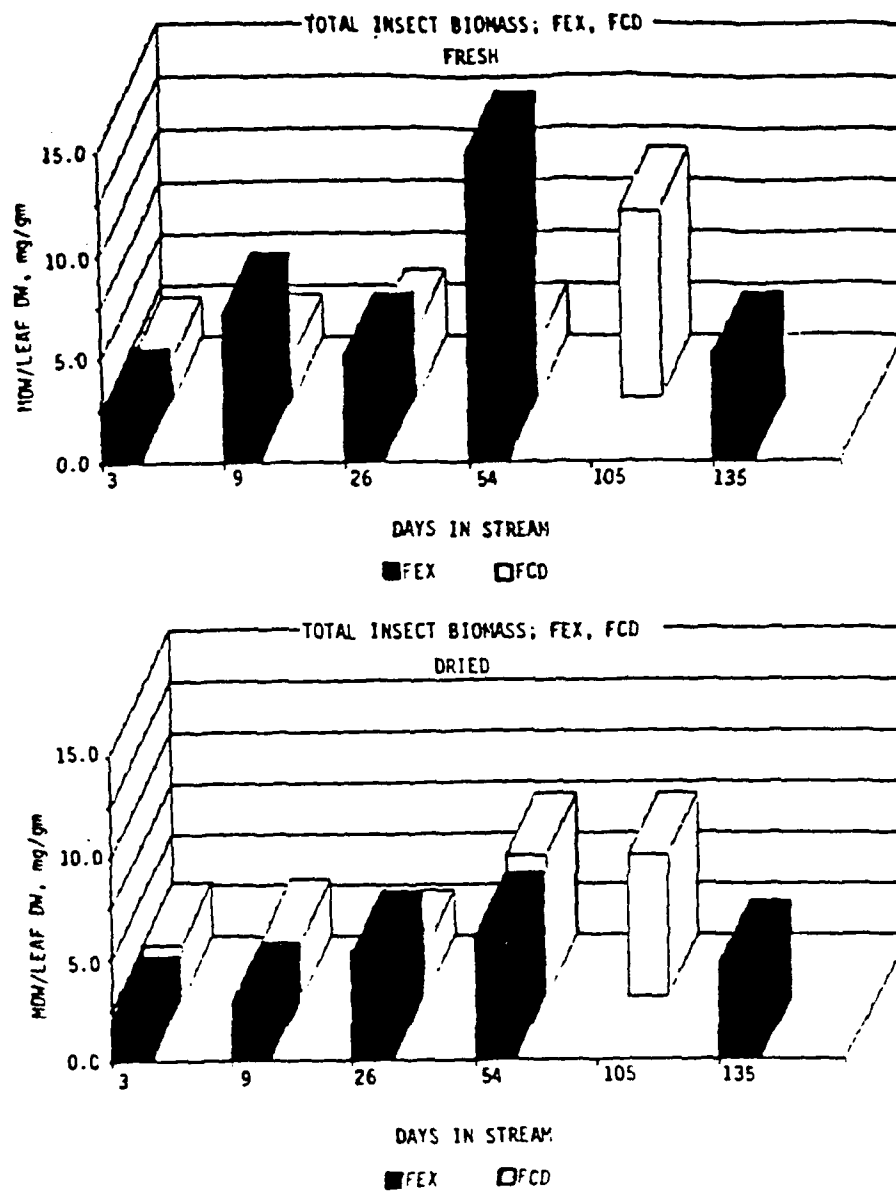


FIGURE 6.5. Mean total biomass of insects, adjusted to mean leaf mass (mg/gm) over time on fresh and oven-dried leaves, Sept. 17, 1985 to January 31, 1986.

Shredder biomass on fresh leaves tended to increase over time (Figure 6.6A). Collector-gatherer biomass on fresh leaves peaked by Day 26 and then decreased (Fig. 6.6B). There were no general trends for predator biomass values (Fig. 6.7).

At FEX, both fresh and dried leaves supported more biomass of collector-gatherers than leaves at FCD. A different pattern emerged for shredders. Fresh leaves supported a higher biomass of shredders than dried leaves at both sites. Table 6.8 gives results from Two-Way ANOVA analyses for the functional feeding groups on Day 26 and Kolmogorov-Smirnov Two Group Tests for shredder differences between fresh versus dried leaves at FCD after 105 days.

Table 6.8
Comparisons for Collector-Gatherer, Shredder and Predator Biomass. Fresh vs. Oven-Dried Leaves at FEX and FCD During Peak Days
Two-Way ANOVA for Site Versus Treatment Differences

Days in Stream	Source	d.f.	MSS	F-ratio	Prob.
COLLECTOR-GATHERERS:					
26	site	1	8.288	5.109	.033*
	treatment	1	.483	.298	.590
	interaction	1	.095	.059	.811
	error	24	1.622	.059	
SHREDDERS:					
26	site	1	.925	1.114	.302
	treatment	1	4.325	5.208	.032*
	interaction	1	.229	.276	.604
	error	24	.831		
105 FCD Kolmogorov-Smirnov Two Group Test for difference between fresh and dried leaves, Dmax = 0.681, p < .05.					
PREDATORS:					
26	site	1	.025	.101	.753
	treatment	1	.243	.991	.329
	interaction	1	.0005	.002	.964
	error	24	.245		

Because insect biomass values according to functional feeding groups incorporate many species, the C.V. values are usually high. Therefore, individual species from each of the three functional feeding groups were analyzed separately.

The mean dry weight per individual (MDW/IND) of one collector-gatherer mayfly, Ephemerella invaria, increased over time on both fresh and oven-dried leaf packs (Fig. 6.8A). This was also the case for a shredder chironomid, B. flavifrons (Fig 6.8B) and for a stonefly predator Isoperla

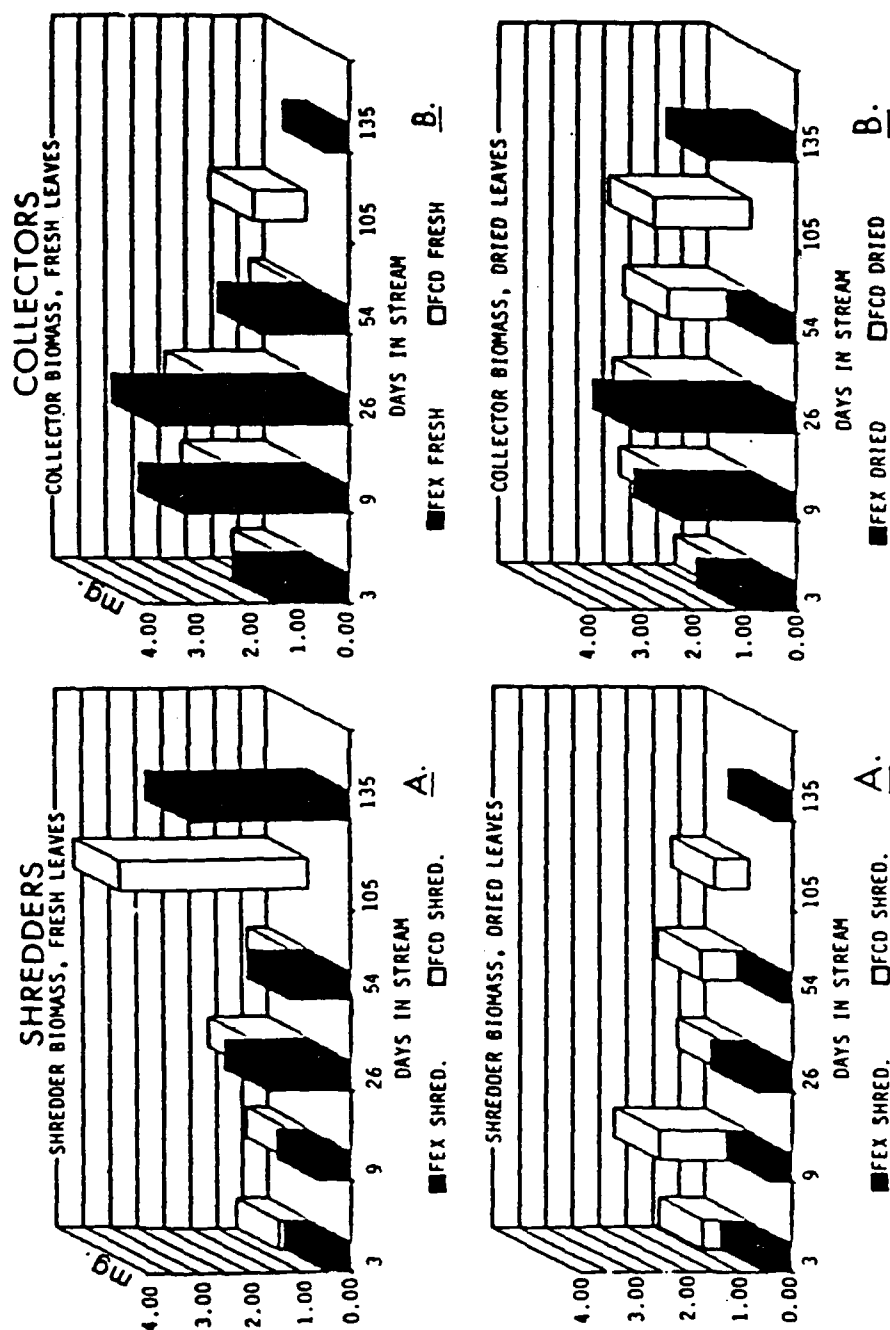


TABLE 6.6A. Mean biomass of shredders (mg.) on fresh and oven-dried leaves from September 17, 1985 to January 31, 1986.

TABLE 6.6B. Mean biomass of collector-gatherers (mg.) on fresh and oven-dried leaves from September 17, 1985 to January 31, 1986.

PREDATORS

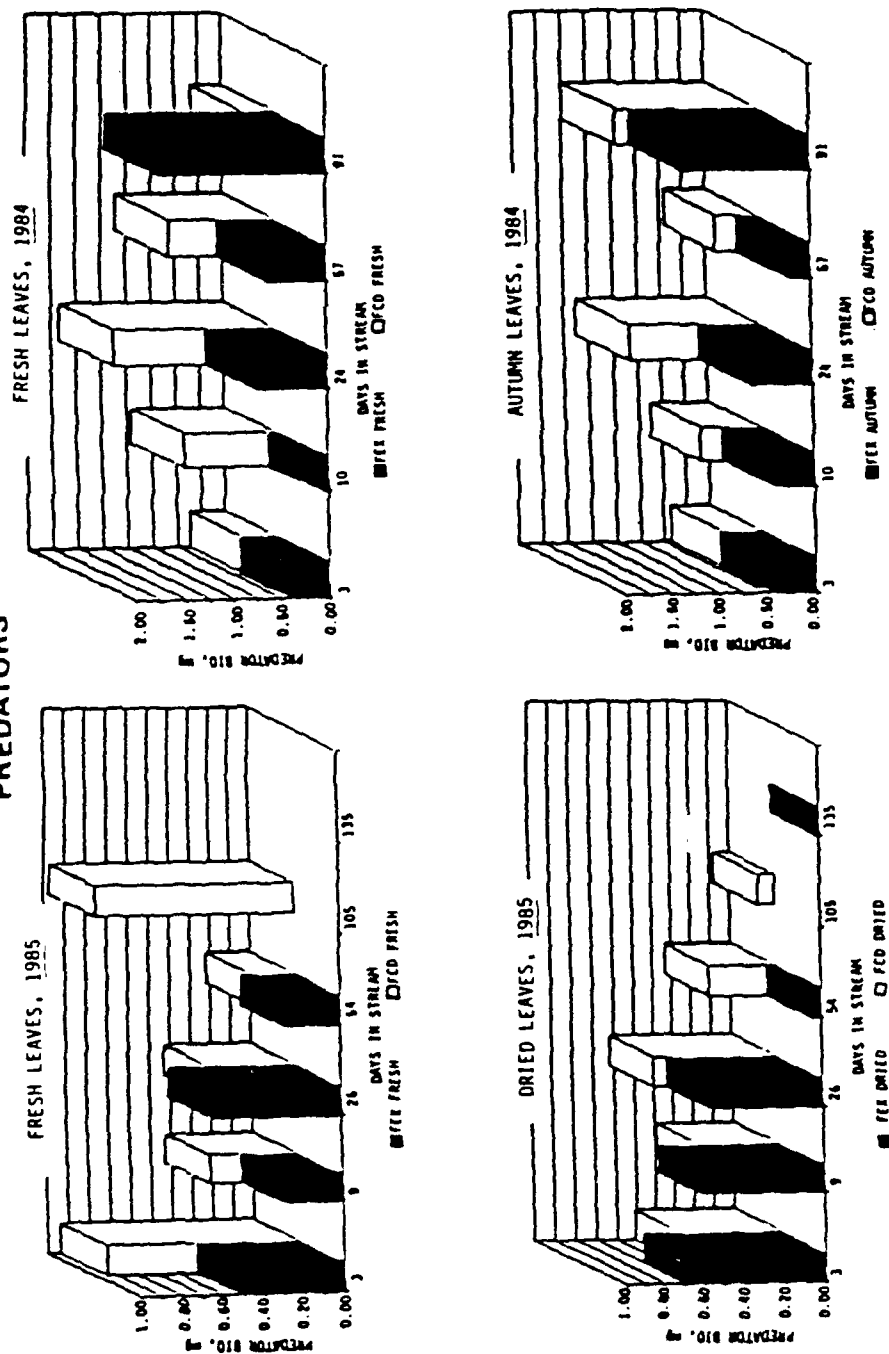


FIGURE 6.7. Changes in mean biomass of predators (mg.) on fresh and autumn leafpacks in 1984 and on fresh and oven-dried leafpacks in 1985.

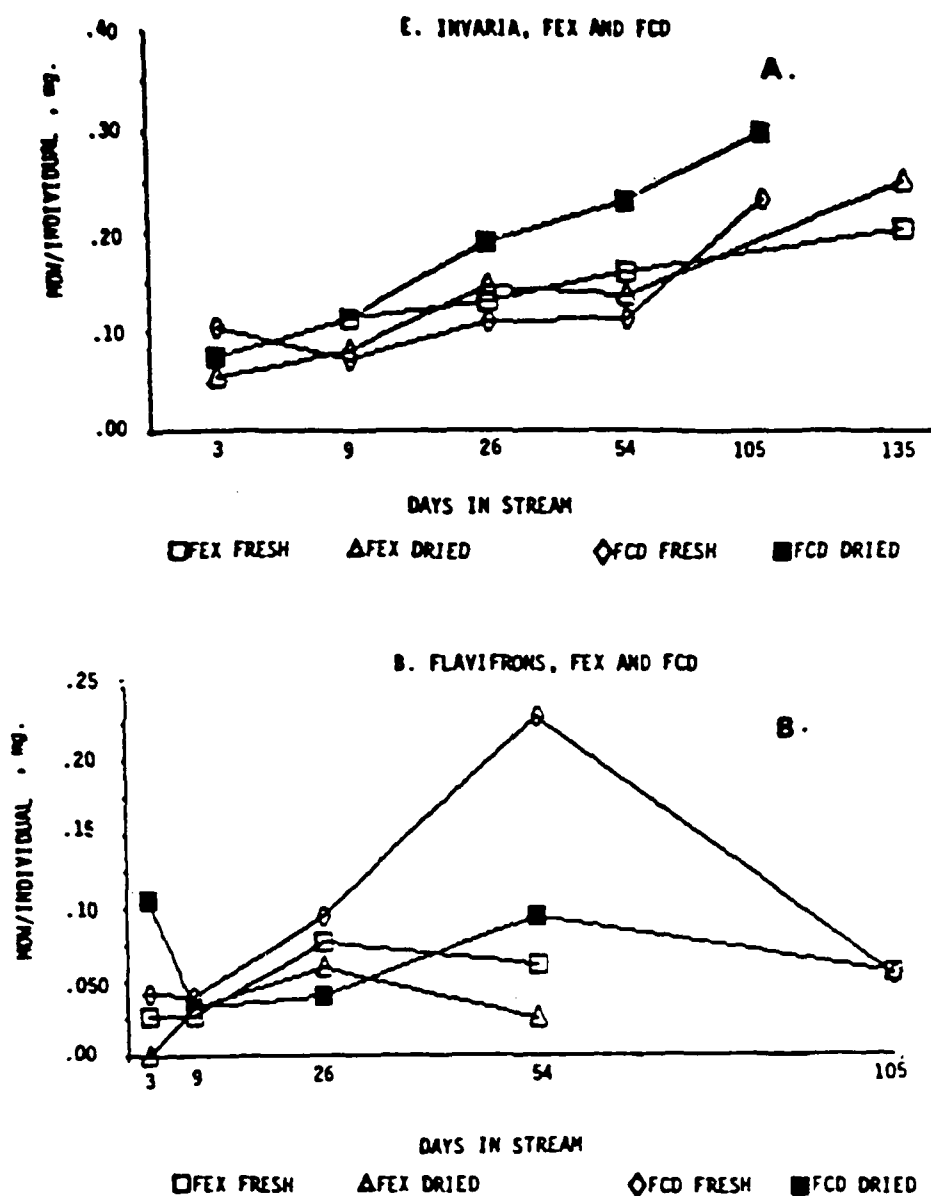


FIGURE 6.8A. Changes in mean dry weight per individual for the mayfly collector, *Ephemera invaria* on fresh and oven-dried leaves at FEX and FCD, Sept. 17, 1985 to Jan. 31, 1986.

FIGURE 6.8B. Changes in mean dry weight per individual for the chironomid shredder, *Brilia flavifrons* on fresh and oven-dried leaves at FEX and FCD, Sept. 17, 1985 to Jan. 31, 1986.

transmarina in 1985 (Fig. 6.9A) or in 1984 (Fig. 6.9B). In none of the three cases did site or treatment make a difference (tested with a Two-Way ANOVA analysis for each collection date):

Comparisons Among Years (1982 - 1986)

Leaf Processing Rates.-- Figure 6.10 shows leaf losses for each study from 1982 through the summer of 1986. 1982-1983 data were from a site (FS1) on the Ford River, which is upstream from FEX (see 1984 Annual Report and Stout et al. 1985). A two-tailed t-test for differences between slopes for a linear regression of fresh leaf dry weights at FS1 in 1982-1983 (days 3 through 111) and at FEX in 1984 (days 3 through 91) showed no significant difference ($t = 0.965$, $d.f. = 44$, $p > 0.10$). The same comparison at FEX for autumn abscised leaves also showed no significant difference in slopes ($t = 0.200$, $d.f. = 44$, $p > 0.10$). Further two-tailed t-tests were run between 1985-86 fall-winter study of fresh leaves and summer of 1986 fresh leaves. At FEX and at FCD, there were no significant differences between slopes for fresh leaves (FEX, $t = .699$, $d.f. = 42$, $p = .244$; FCD, $t = 1.443$, $d.f. = 44$, $p = .078$). (The fall of 1985 fresh leaf data through Day 54 and the summer of 1986 fresh leaf data through Day 56, excluding Day 45, were compared.)

Table 6.8 presents processing coefficient values (-k) from 1982 through the summer of 1986.

Table 6.8
Processing Coefficients (-k) For Fresh and Autumn Leaves
on the Ford River

Season and Year	FEX		FCD	
	Fresh	Autumn	Fresh	Autumn
Fall, Winter 1982-83*	.0171	.0086	-	-
Fall, Winter 1984-85	.0152	.0081	.0150	.0060
Fall, Winter 1985-86	.0320	-	.0150	-
Summer 1986	.0206	-	.0266	-
Fall, Winter 1986	.0101	.0033	.0109	.0026

* 1982-1983 site was FS1, 2 km. upstream of the FEX site.

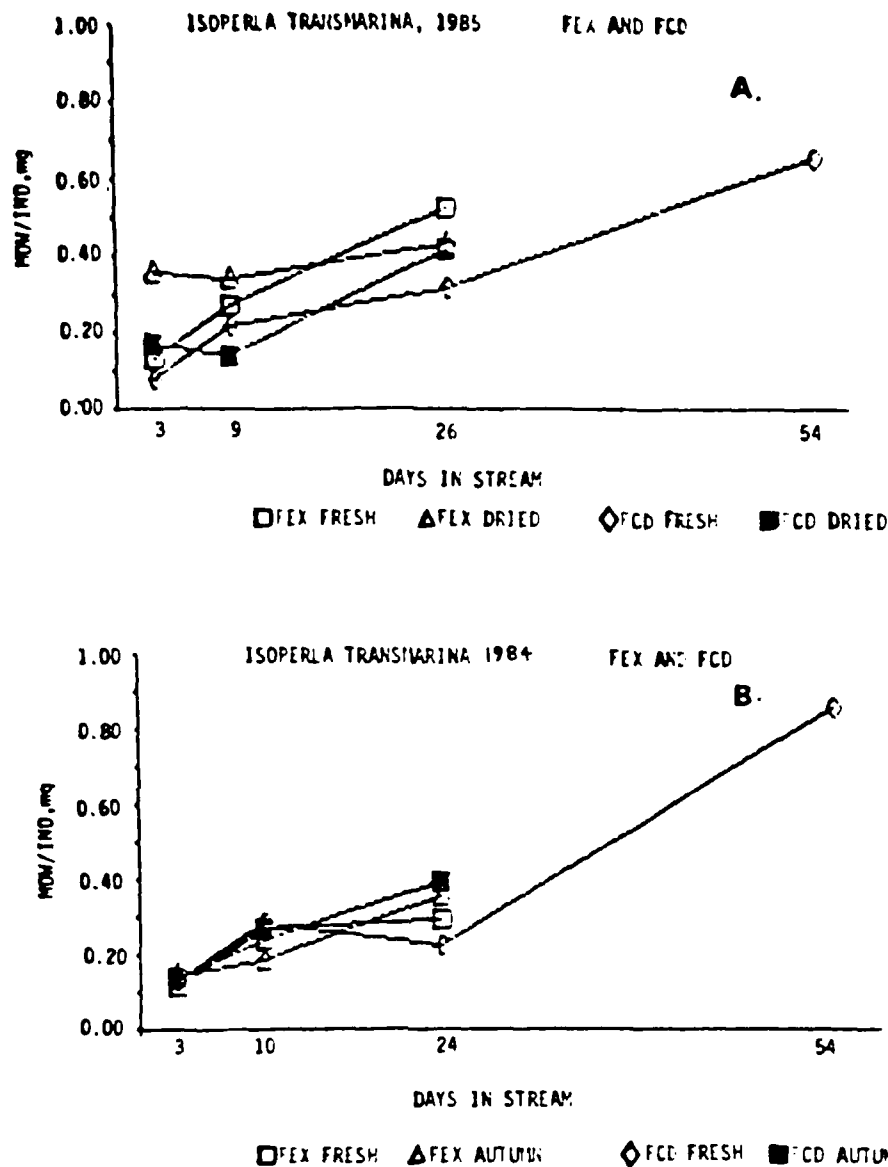


FIGURE 6.9A Changes in mean dry weight per individual for *Isoperla transmarina* on fresh and oven-dried leaves at FEX and FCD, September 17 to November 9, 1985.

6.9B Changes in mean dry weight per individual for *Isoperla transmarina* on fresh and autumn-senesced leaves at FEX and FCD, September 19 to November 11, 1984.

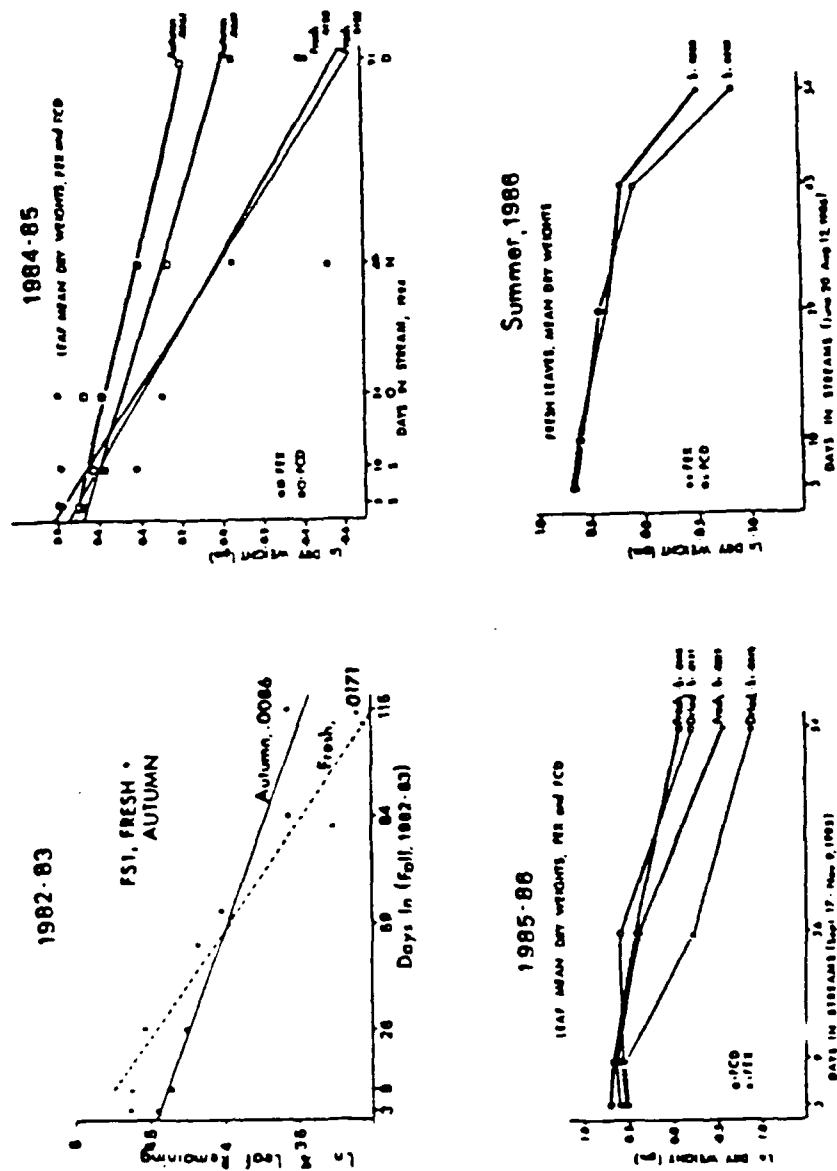


FIGURE 6.10 Leaf losses and leaf processing rates (-k). 1982-83 = fresh vs. autumn; 1984-85 = fresh vs. autumn; 1985-86 = fresh vs. over-dried; 1986 = fresh summer leaves.

Fresh leaves and oven-dried fresh leaves were processed significantly faster than were autumn abscissed leaves for all the studies.

The high $-k$ values for fresh leaves at FEX in the fall-winter of 1985 may have been related to extensive flooding and scouring prior to Day 54 collections. (FEX contains more cobble and pebbles than FCD.) Processing rates would be expected to be higher for fresh leaves during the summer (see summer of 1986 values) than for fresh leaves during the fall when water temperature and bacterial activity are lower. If the leaf losses in the fall of 1985 at FEX are attributable to more extensive scouring there and more deposition of sand at the FCD site, the data agree with what one would expect for summer versus fall-winter differences in processing rates.

When the 1986-1987 fall-winter leaf study is completed (fresh versus autumn senescent leaves), an analysis of covariance for processing rates of fresh and autumn leaves over the years will be performed.

Structural Community Parameters.-- The 1982-1983, 1984-1985, and 1985-1986 fall-winter data will be compared; (Processing of insects on leaves for the summer of 1986 and fall-winter of 1986-87 will not be completed until 1987.

The patterns for diversity (H') changes over time were similar for 1982 and 1985 after the initial conditioning phase (9 days); diversity continually declined over time (Fig. 6.11). The same pattern including 1984 existed for evenness (J') for all leaf treatments (Fig. 6.12). In 1982, numbers of taxa decreased steadily over time; in 1984 numbers of taxa increased for the first month's incubation period and then declined thereafter. In 1985-86 there was no significant change for the first month; after which, the number of taxa decreased (Fig. 6.13). Thus, all the data were similar after three to four weeks. Numbers of individuals peaked after three weeks' incubation for all three years as well (Compare Fig. 6.3 with p. 114, 1985 Annual Report). The increase in numbers of individuals each year was primarily attributable to an increase in percent dominance of chironomids over time (Fig. 6.14).

Functional Community Parameters.-- In 1982, the FS1 site had higher insect biomass on fresh leaves than were found at either the FEX or FCD sites in 1984 and 1985 (Fig. 6.15). In 1984 and 1985, the total insect biomass was higher on leaves at FEX than at FCD.

Only on Day 26 in 1985 was the collector-gatherer biomass higher at FEX than at FCD (Fig. 6.6). There was no difference between sites in 1984 (p. 124, 1985 Annual Report). The mean

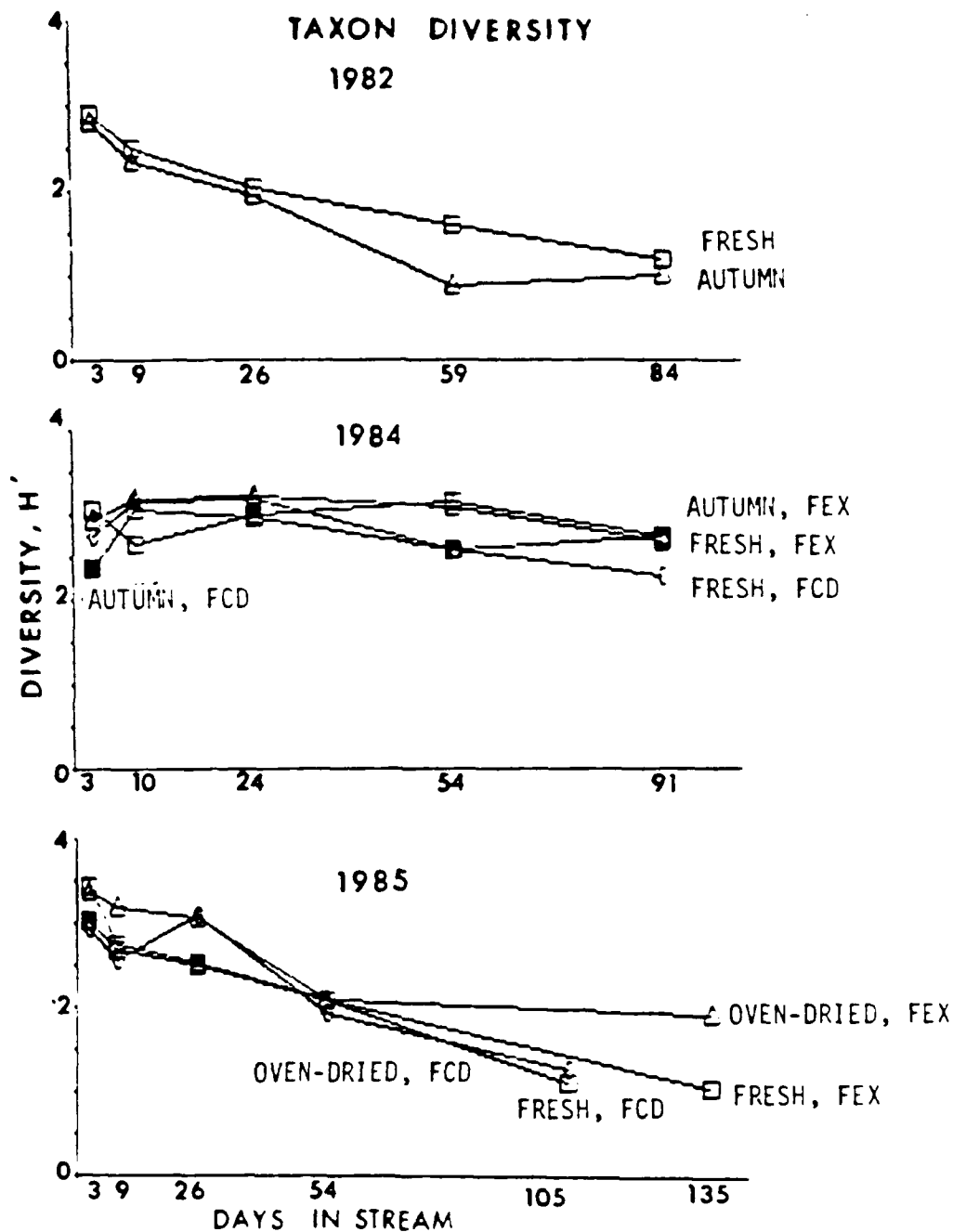


FIGURE 6.11 Insect taxon diversity (H') for insects on leaves. 1982 = fresh vs. autumn. 1984 = fresh vs. autumn. 1985 = fresh vs. oven-dried.

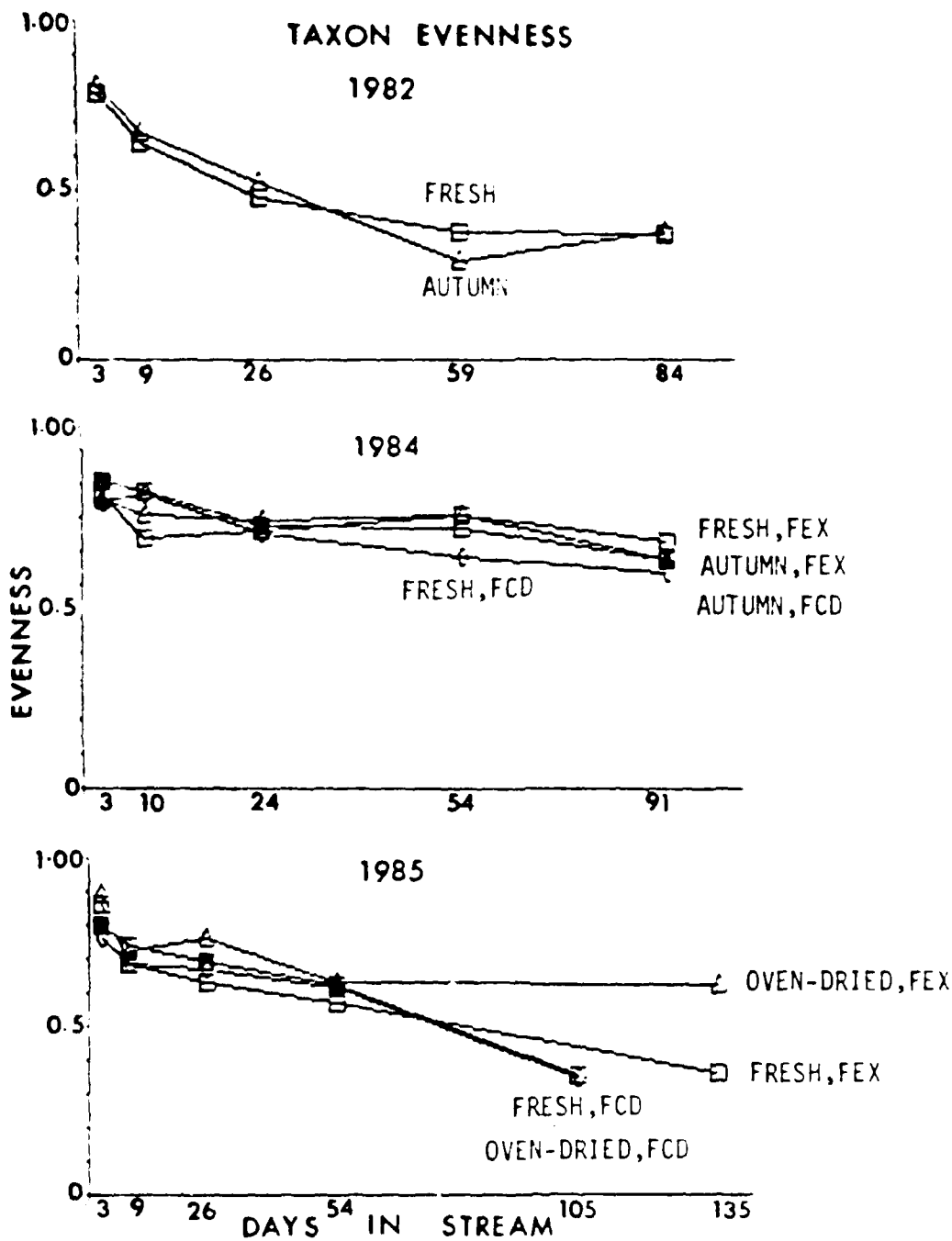


FIGURE 6.12. Insect taxon evenness (J') for insects on leafpacks. 1982 = fresh vs. autumn. 1984 = fresh vs. autumn. 1985 = fresh vs. oven-dried.

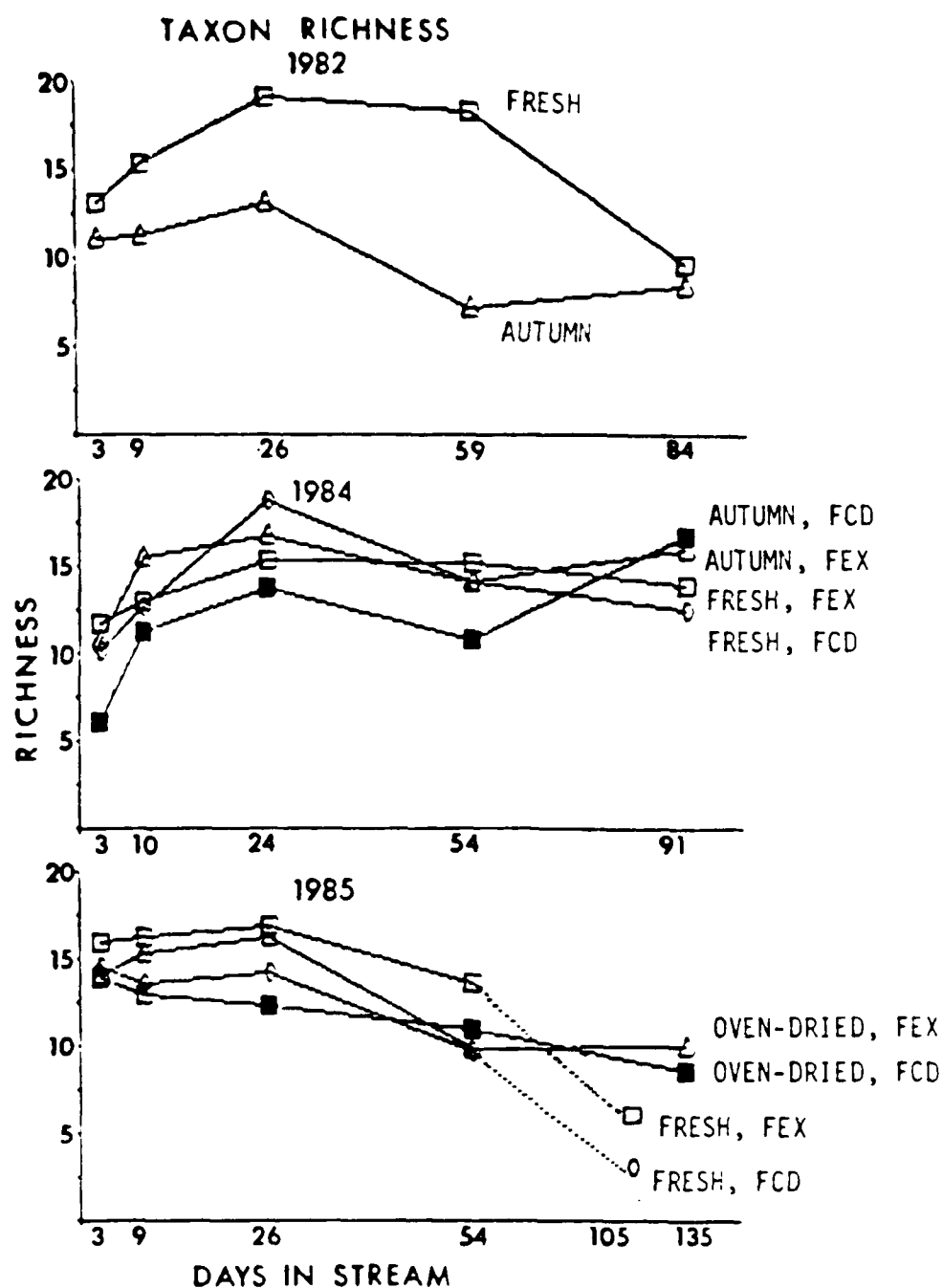


FIGURE 6.13 Insect taxon richness (S) for insects on leafpacks.
1982 - fresh vs. autumn. 1984 = fresh vs. autumn.
1985 = fresh vs. oven-dried.

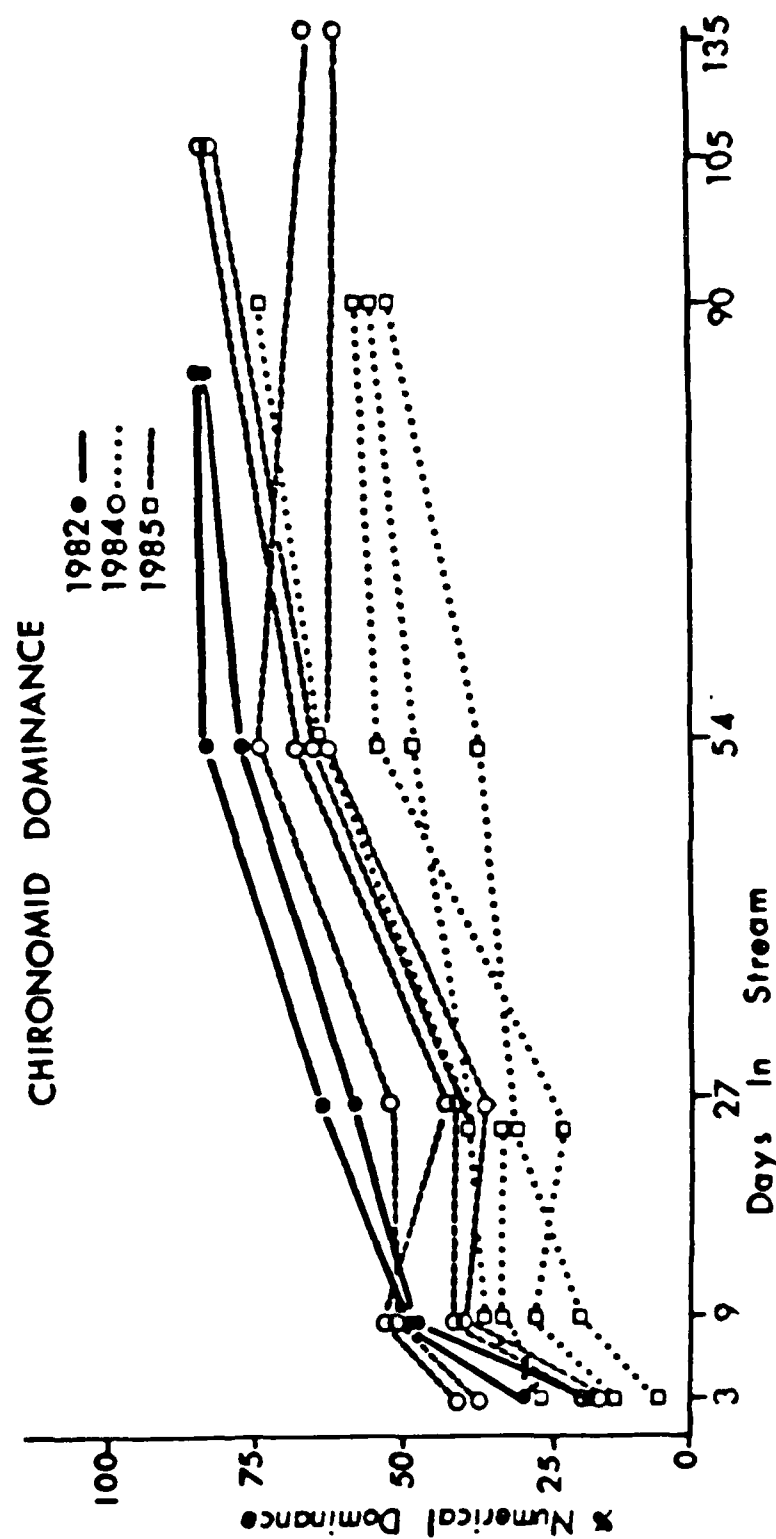


FIGURE 6.14 Chironomid numerical dominance on leafpacks. 1982-83 = lines. 1984-85 = dots. 1985-86 = dashes.

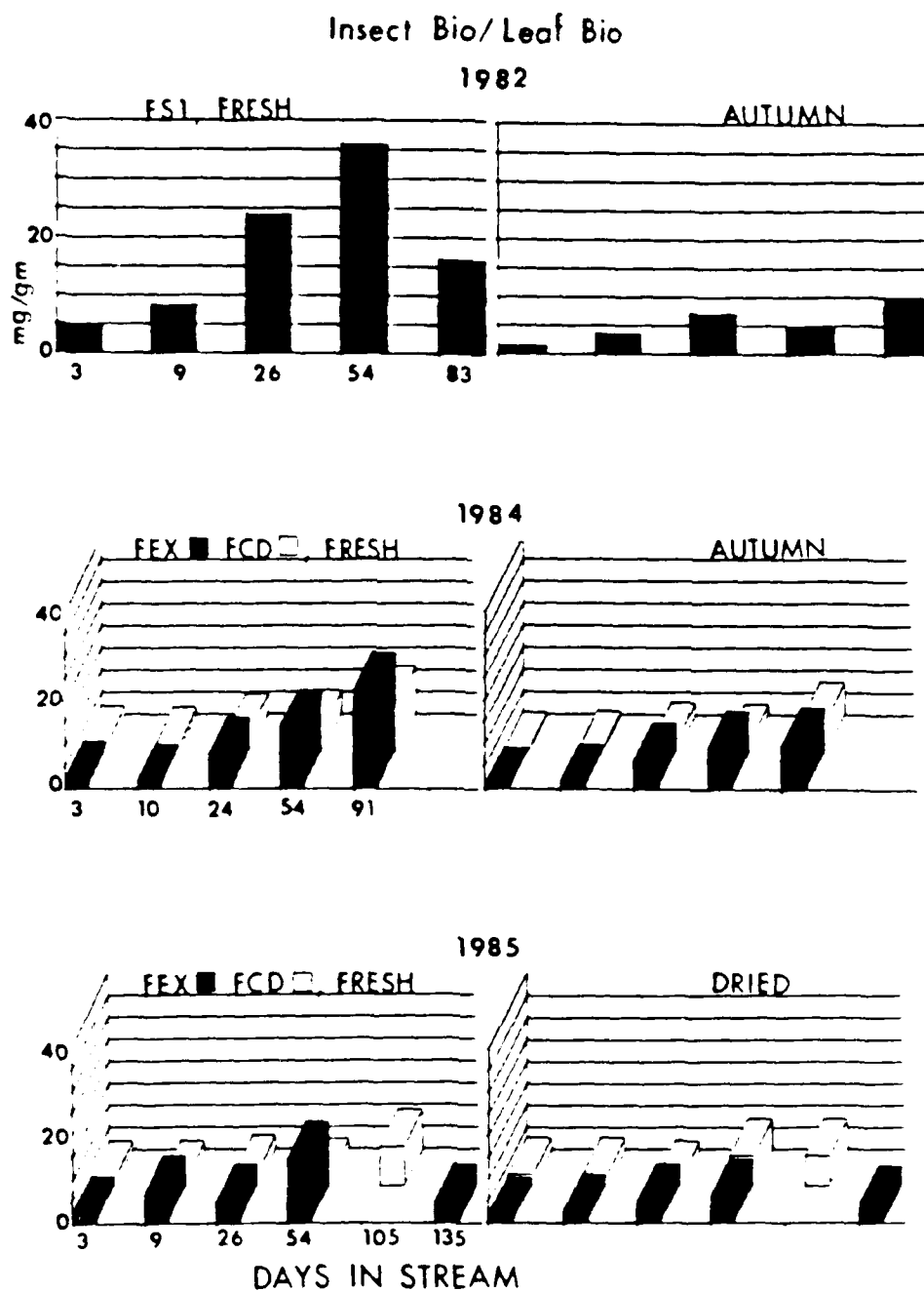


FIGURE 6.15. Mean Insect biomass, adjusted to leaf biomass, in 1982 (fresh vs. autumn), 1984 (fresh vs. autumn), and 1985 (fresh vs. oven-dried).

dry weight of the mayfly collector, Ephemergella invaria, consistently increased at similar rates over time at FEX and FCD on all leaf treatments in 1984 and 1985 (Fig. 6.17), suggesting that we are monitoring seasonal growth rates of this species, rather than site effects or leaf nutritive quality. This species was not monitored in 1982.

Shredder biomass in 1985-86 was significantly higher on fresh than on dried leaves on days 26, 105 and 135. In 1982 and 1984 shredder biomass was higher on fresh than on autumn senescent leaves. It is possible that both autumn senescent and oven-dried green leaves are less "attractive" to shredders than are fresh, green Tag Alder leaves.

The mean dry weight per individual values for the shredder B. flavifrons was higher on fresh than on autumn-abscissed leaves in 1982 and 1984. No pattern was evident in 1985 for fresh and oven-dried leaves (Fig. 6.18).

The mean dry weight per individual values for the stonefly predator, I. transmarina were similar for all leaf treatments in 1984 and in 1985 -- the two years that the species was monitored (Fig. 6.9).

In general, total insect biomass values tended to show repeatable patterns across years; biomass values according to functional feeding groups did not; but MDW/IND values for particular species within each functional feeding group showed the most consistent and similar patterns across years.

Future Plans for this Element

Next year (1987), the fresh and autumn abscissed leaf studies will be initiated at the same time (mid-September), as we collected sufficient abscissed leaves in 1986 for two years' work. The summer fresh leaf study in 1986 will also be repeated in 1987. If time is insufficient for identification of insects, at least processing coefficients will be determined for the summer leaves at the two sites.

Coefficient of Variation (C.V.) values for \bar{x} , H' , J' , S and biomass of selected species were low. Using a power test, five replicates per treatment were sufficient over most of the collection dates to state that 95% of the time the true mean was within $\pm 40\%$ of the estimated mean at an alpha level of .05. Even so, seven replicates per treatment per collection date were taken in 1985 and 1986 to increase the probability that C.V. values would be below 20% for most parameters throughout all collection periods. Seven replicates per treatments per site will continue to be taken in future years, as there is sufficient person-power to process the additional leafpack samples.

E. INVARIA, FEX and FCD

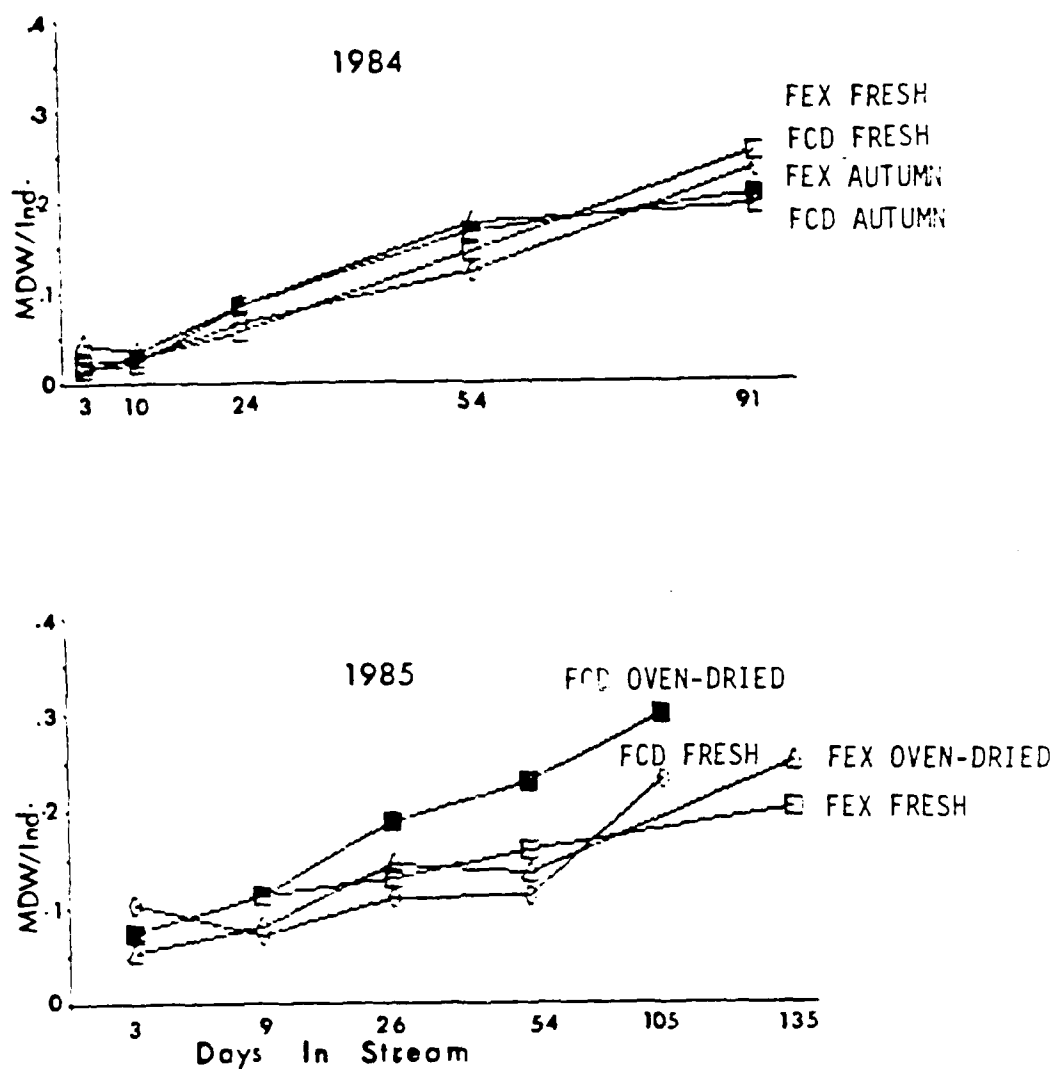


FIGURE 6.16 Mean dry weight per individual values over time for *Ephemerella invaria*. 1984 = fresh vs. autumn leaves. 1985 = fresh vs. oven-dried leaves

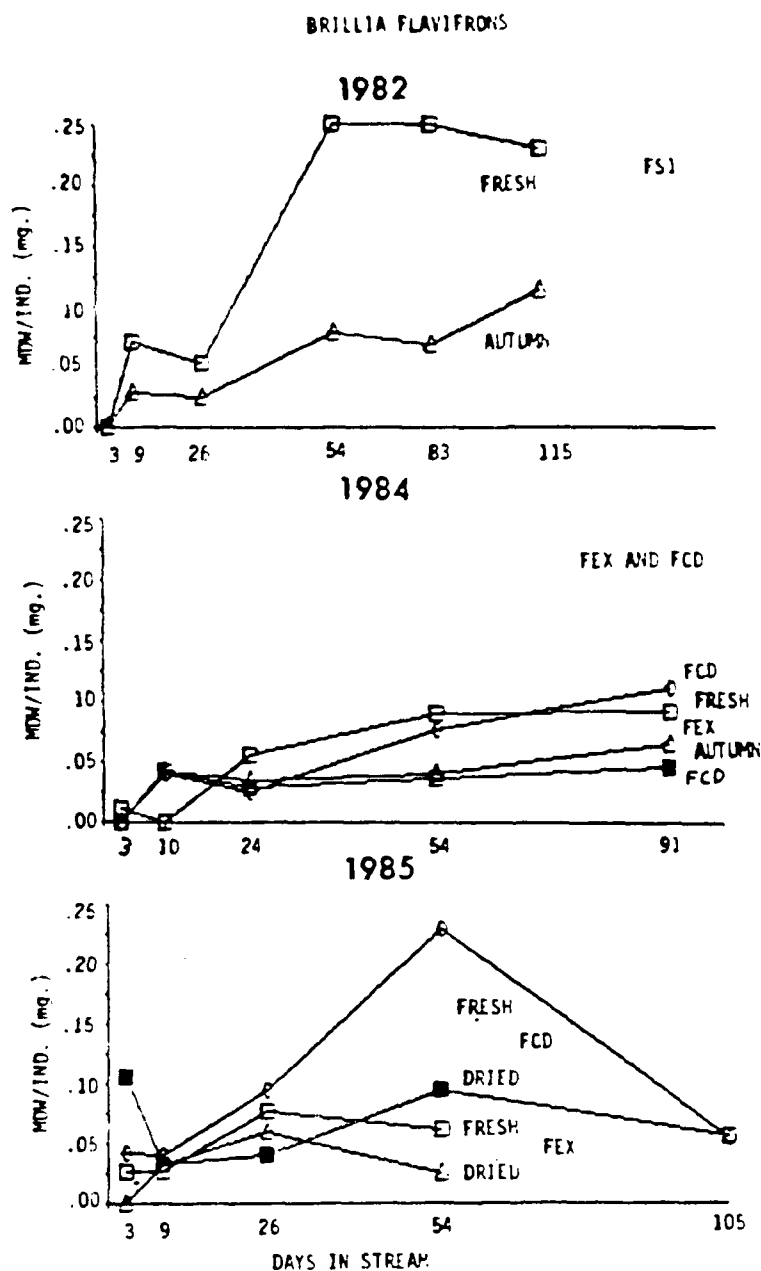


FIGURE 6.17 Mean dry weight per individual values over time for *Brillia flavifrons*. 1982 = fresh vs. autumn at FS1. 1984 = fresh vs. autumn at FEX and FCD. 1985 = fresh vs. autumn at FEX and FCD

All parameters previously used will continue to be followed at the FEX and FCD sites. Changes in predator biomass along with selection of the most common predator species, Isoperla transmarina, will continue to be included in future work for this element.

Summary

Leaf processing rates (-k) were not significantly different for 1982, 1984, 1985 and 1986. H' and J' values were also similar. Numbers of species (S) remained higher over time in 1984 as compared with 1982-1983 and 1985-1986 data. Percent dominance of chironomids on leaves was similar for all the studies. One shredder, B. flavifrons, showed similar numerical and size-class patterns in 1982-1983 and 1984. In 1985, both numbers were lower and size-class changes were not as distinctive as in previous years. The MDW/IND values for E. invaria, a collector-gatherer, and for I. transmarina, a predator, were similar in 1984 and 1985. (1984 was the first year they began being monitored.) C.V. values, except for total biomass and functional feeding group biomass, were below 18%.

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Element 7 - Fish Community Composition and Abundance

Changes from Synopsis - None.

Objectives

The overall objective of this element is to examine the effects of the Navy's ELF project on the fish community structure and movement in the Ford River. The specific objectives are to determine and monitor: 1) The fish community species composition, structure and relative abundance at both ELF sites; 2) The relative mobility of the fish community excluding brook trout in the Ford River; and 3) The age, growth, and condition of selected species in the Ford River.

Materials and Methods

Two fyke net sites (FCD and FEX) and two weir sites (FCU and TM) were used in this study (Figure 7.1). The two fyke net sites were used in all parts of the study, and weir sites were operated only for the capture of fish marked at the lower sites for the fish community movement study. Sampling dates for 1983 through 1985 were reported in previous annual reports. Sampling for the 1986 season commenced on May 21 and continued when weather permitted until September 19. The number of sampling days for each year is reported in Table 7.1.

At FCD and FEX, two 1/2 inch bar mesh fyke nets were fished (one facing upstream and one facing downstream). At FCU and TM, a weir constructed of 1/2 inch hardware cloth was used. The weir design was a variation of those used by Hall (1972). All gear was fished continuously for 4 sampling days per week and checked every 24 hours.

All fish were enumerated, measured, weighed and marked by a fin clip distinctive for that site. The live fish were then returned to the water upstream or downstream from the station in the direction of travel.

Results and Discussion

A. Species composition

Thirteen species from five orders and eight families were collected at FEX in 1986 (Table 7.2) using 1/2 inch bar mesh fyke nets. No change in the number of species or orders was found in 1986 when compared to 1985. The number of families was one less than found in 1984 and 1985 although the same as collected in 1983. The changes in the overall FEX species composition can be attributed to changes in the catch of rare species.

The catch at FCD in 1986 consisted of sixteen species from ten families and five orders (Table 7.3). This represents a decline of one species, family and order from previous years. Again, as in the FEX samples, the only changes in the species composition occurred in the rare species which occur in low numbers.

The species composition was consistently higher at FCD than at FEX which continues the trend noted in previous years reports. This trend can be attributed to the differences in habitat heterogeneity at FCD, and the location of FCD which is closer to a large warmwater marsh and

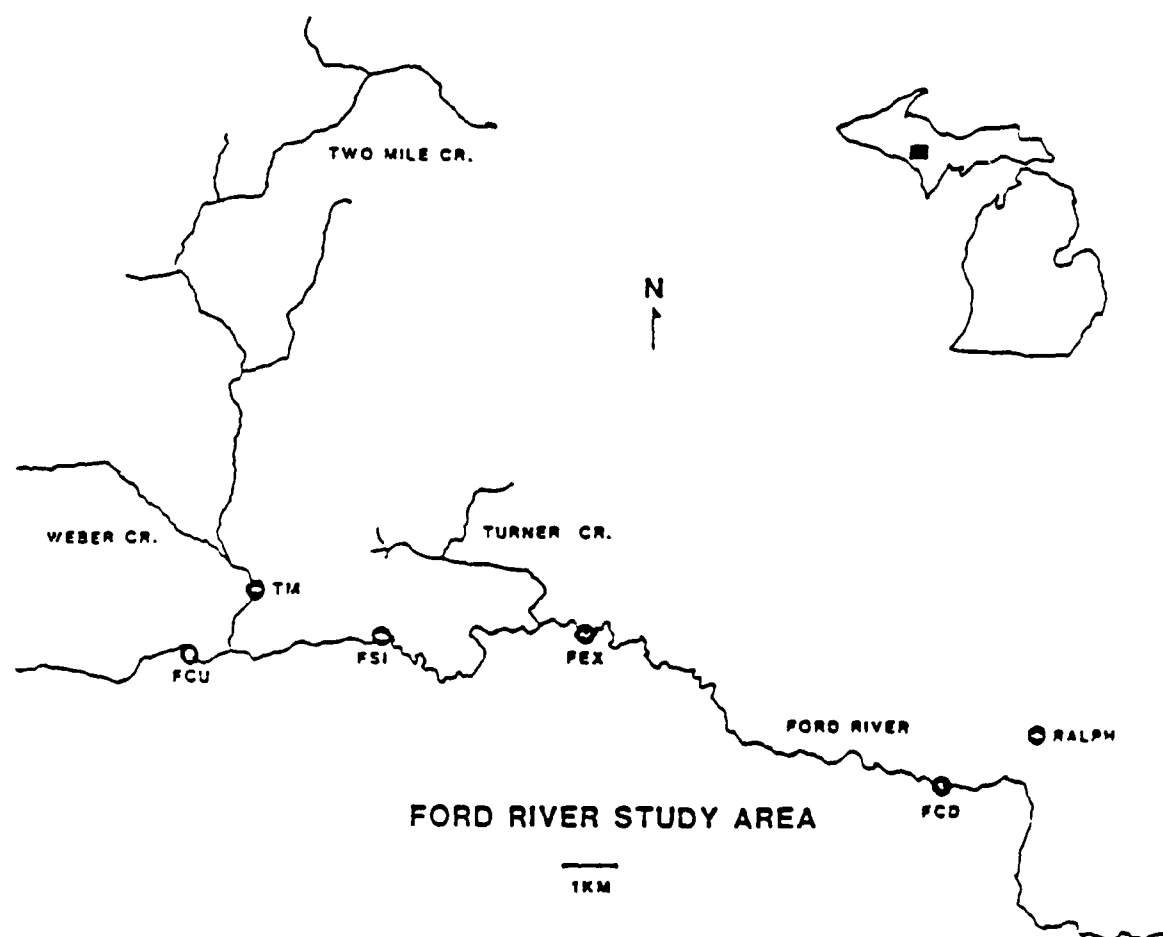


Figure 7.1 Ford River - ELF Fisheries Study Sites

Table 7.1. Number of net-days at each site from 1983-86

Site	Year			
	1983	1984	1985	1986
TM	---	122	61	51
FCU	---	47	54	52
FEX	20	77	46	45
FCD	20	93	56	52

Table 7.2. Fish species collected at FEX from May 1983 to September 1986 using 1/2" mesh fyke nets. Scientific and common names are from Robins et al. 1980.

Scientific Name	Common Name	FEX			
		1983	1984	1985	1986
Cypriniformes					
Catostomidae					
<u>Catostomus commersoni</u> (Lacepede)	White sucker	x	x	x	x
<u>Hypentelium nigricans</u> (Lesueur)	Northern hog sucker		x		
Cyprinidae					
<u>Notropis cornutus</u> (Mitchill)	Common shiner	x	x	x	x
<u>Rhinichthys atratulus</u> (Hermann)	Blacknose dace	x	x	x	x
<u>Rhinichthys cataractae</u> (Valenciennes)	Longnose dace	x	x	x	x
<u>Semotilus atromaculatus</u> (Mitchill)	Creek chub	x	x	x	x
<u>Semotilus margarita</u> (Cope)	Pearl dace	x	x		x
Gadiformes					
Gadidae					
<u>Lota lota</u> (Linnaeus)	Burbot	x	x	x	x
Perciformes					
Centrarchidae					
<u>Ambloplites rupestris</u> (Rafinesque)	Rock bass		x	x	x
<u>Micropterus dolomieu</u> (Lacepede)	Smallmouth bass		x		
<u>Micropterus salmoides</u> (Lacepede)	Largemouth bass		x		x
Cottidae					
<u>Cottus bairdi</u> (Girard)	Mottled sculpin	x	x	x	x
Percidae					
<u>Percina maculata</u> (Girard)	Blacksided darter	x	x	x	x

Scientific Name	Common Name	FEX			
		1983	1984	1985	1986
Petromyzontiformes					
Esocidae					
<u>Ichthyomyzon fossor</u> (Reighard and Cummins)	Northern brook lamprey		x		
<u>Petromyzon marinus</u> (Linnaeus)	Sea lamprey		x	x	x
Salmoniformes					
Esocidae					
<u>Esox lucius</u> (Linnaeus)	Northern pike	x	x	x	x
Salmonidae					
<u>Salvelinus fontinalis</u> (Mitchill)	Brook trout	x	x	x	x
Umbridae					
<u>Umbra limi</u> (Kirtland)	Central mudminnow	x	x	x	

Table 7.3. Fish species collected at FCD from May 1983 to September 1986 using 1/2" mesh fyke nets. Scientific and common names are from Robins et al. 1980.

Scientific Name	Common Name				FCD			
					1983	1984	1985	1986
Clupeiformes								
Clupeidae								
<u>Alosa pseudoharengus</u> (Wilson)				Alewife	x			
Cypriniformes								
Catostomidae								
<u>Catostomus commersoni</u> (Lacepede)				White sucker	x	x	x	x
<u>Hypentelium nigricans</u> (Lesueur)				Northern hog sucker		x		
Cyprinidae								
<u>Notropis cornutus</u> (Mitchill)				Common shiner	x	x	x	x
<u>Pimephales promelas</u> (Rafinesque)				Fathead minnow				x
<u>Phoxinus eos</u> (Cope)				Northern redbelly dace	x			x
<u>Rhinichthys atratulus</u> (Hermann)				Blacknose dace		x	x	x
<u>Rhinichthys cataractae</u> (Valenciennes)				Longnose dace	x	x	x	x
<u>Semotilus atromaculatus</u> (Mitchill)				Creek chub	x	x	x	x
<u>Semotilus margarita</u> (Cope)				Pearl dace	x	x	x	x
Gadiformes								
Gadidae								
<u>Lota lota</u> (Linnaeus)				Burbot	x	x	x	x
Perciformes								
Centrarchidae								
<u>Ambloplites rupestris</u> (Rafinesque)				Rock bass	x	x	x	x
<u>Lepomis gibbosus</u> (Linnaeus)				Pumpkinseed sunfish		x	x	
<u>Micropterus dolomieu</u> (Lacepede)				Smallmouth bass		x		
<u>Micropterus salmoides</u> (Lacepede)				Largemouth bass		x		x
Cottidae								
<u>Cottus bairdi</u> (Girard)				Mottled sculpin	x	x	x	x
Percidae								
<u>Percina maculata</u> (Girard)				black-sided darter	x	x	x	x

Scientific Name	Common Name	FCD			
		1983	1984	1985	1986
Petromyzontiformes					
Petromyzontidae					
<u>Ichthyomyzon</u>					
<u>fossor</u> (Reighard and Cummins)					
<u>Petromyzon</u>					
<u>marinus</u> (Linnaeus)	Sea lamprey	x	x	x	x
Salmoniformes					
Esocidae					
<u>Esox</u>					
<u>lucius</u> (Linnaeus)	Northern pike	x	x	x	x
Salmonidae					
<u>Salvelinus</u>					
<u>fontinalis</u> (Mitchill)	Brook trout	x	x	x	x
Umbridae					
<u>Umbra</u>					
<u>limi</u> (Kirtland)	Central mudminnow	x	x	x	x
Siluriformes					
Ictaluridae					
<u>Ictalurus</u>					
<u>nebulosus</u> (Lesueur)	Brown bullhead			x	

to Lake Michigan. All of the differences in the community composition between sites were in the uncommon species, thus overall the two sites continued to be similar in species composition.

B. Species abundance

Numeric. The fish community at FEX was dominated by five species with the majority of the individuals caught from the cyprinid family (Table 7.4). Common shiners and creek chubs consisted of over 45% of the catch and this percentage was consistent from year to year. The species structure was stable from year to year with all species having coefficients of variation on their combined percent catch of less than 45%. The catch component made up of common shiners was the most stable with a combined percent catch coefficient of variation of 7%. White suckers and burbot demonstrated the greatest fluctuations in number with coefficients of variation of 41% and 31% respectively. Overall, the community at FEX continued to be stable in relative numeric abundance with creek chubs and common shiners the dominant two species.

The relative numeric abundance of the catch at FCD was dominated by the same species as at FEX with the majority of the catch from the cyprinid family (Table 7.4). Common shiners and creek chubs were again the dominant species with over 55% of the catch and this percentage was consistent from year to year. This site also demonstrated a stable species abundance with all species having combined percentage catch coefficients of variation under 50%. Common shiners were the most stable catch component at FCD with a catch percentage coefficient of variation of 6%. White suckers and burbot catches were the most variable with catch percentage coefficients of variation of 47% and 36% respectively. The major difference between the two sites was the higher percent catch of common shiners at FCD and lower percent catch of brook trout and burbot at FCD. These differences can probably be attributed to the differences in habitat between the two sites. Overall, the sites continued to be similar in species composition and demonstrated stable relative abundances from year to year.

Biomass. Catch percentage by biomass showed different trends in community structure than by number at both sites (Table 7.5). The FEX fish community was dominated in biomass by the same five species as was found by the numeric analysis although the dominant species changed. Brook trout and white suckers dominated the catch biomass with over 45% of the catch each year. Percent catch by biomass was more variable than percent catch by number although most species (except white suckers) had coefficients of variation of less than 50%. Burbot biomass was the most consistent (C.V.=23%) and white sucker catches were the most variable (C.V.=79%).

The catch biomass at FCD showed similar trends to FEX with the same five species dominating the catch (Table 7.5). Brook trout and white suckers were the dominant species with the cyprinid biomass being higher than at FEX. Brook trout percent catch by biomass was the most stable (C.V.=23%) and white sucker percent catch by biomass were the most variable (C.V.=100). Overall, the relative abundance by biomass showed similar trends at both sites with the major difference in the increase in percent cyprinid biomass at FCD.

Table 7.4. Percent catch by number of the dominant fish species at each ELF site from May 1983 to September 1986 using 1/2" mesh fyke nets.

Species	Year				
	1983	1984	1985	1986	Combined
FEX					
Brook trout	12.3	10.2	16.0	10.6	12.3 \pm 2.6
Burbot	20.1	24.1	12.9	13.4	17.6 \pm 5.4
Common Shiner	23.0	27.1	24.7	24.9	24.9 \pm 1.7
Creek chub	22.7	16.6	33.3	29.7	25.6 \pm 7.4
White sucker	8.8	8.6	5.6	14.8	9.5 \pm 3.9
Other species	13.0	13.2	7.5	6.6	10.1 \pm 3.5
FCD					
Brook trout	13.8	11.3	10.6	6.7	10.6 \pm 2.9
Burbot	17.0	6.0	8.3	9.5	10.2 \pm 4.8
Common shiner	33.9	35.6	38.6	37.4	36.4 \pm 2.1
Creek chub	21.1	25.4	26.2	27.9	25.2 \pm 2.9
White sucker	5.5	13.1	7.6	9.3	8.9 \pm 3.2
Other species	8.6	8.1	8.7	9.2	8.7 \pm 0.5

Table 7.5 Percent catch by biomass of the dominant fish species at each ELF site from May 1983 to September 1986 using 1/2" fyke nets.

Species	Year				
	1983	1984	1985	1986	Combined
FEX					
Brook trout	33.4	23.2	60.3	24.7	35.4 ± 17.2
Burbot	16.2	13.6	9.2	12.3	12.8 ± 2.9
Common shiner	10.1	3.5	9.7	13.8	9.3 ± 4.3
Creek chub	16.9	7.5	15.9	23.5	16.0 ± 6.7
White sucker	17.8	46.4	4.1	20.8	22.3 ± 17.6
Other species	5.6	5.8	0.8	4.9	4.3 ± 2.3
FCD					
Brook trout	29.0	35.5	43.3	25.9	33.4 ± 7.7
Burbot	12.6	2.0	8.6	6.9	7.5 ± 4.4
Common shiner	17.2	4.0	18.5	18.6	14.6 ± 7.1
Creek chub	22.5	6.2	17.6	21.9	17.0 ± 7.6
White sucker	7.7	49.9	7.6	15.6	20.2 ± 20.2
Other species	11.0	2.4	4.4	10.1	7.0 ± 4.2

Diversity. Shannon-Weiner diversity values showed a decline at both sites in 1986 (Table 7.6). This trend was significant at FEX but not at FCD (Kruskal-Wallis Test, $p=0.05$). No significant differences were found between sites in index values in any year (Mann-Whitney U Test, $p=0.05$). Overall, diversity values continued to be similar between sites and generally similar from year to year.

C. Catch Statistics

Catch rates. Catch rates at both FEX and FCD showed a large amount of variance for all species as one would expect from catches having a clumped distribution (Table 7.7). White suckers, common shiners and creek chubs all have high spring-early summer catch rates because of spawning movements. Brook trout and burbot catch rates are also high in the early summer but this is attributed to water temperatures increasing above optima for both species. White suckers also show an additional peak in the late summer-early fall.

FEX catch rates for common shiners, creek chubs and white suckers all showed an increase from 1984-1986 with 1986 catch rates similar to high 1983 catch rates (Table 7.7). Brook trout and burbot catches showed no trend during the 1983-1986 period.

Catch rates at FCD for burbot, common shiners, creek chubs and white suckers showed no trends during the 1983-1986 period (Table 7.7). Brook trout catch rates declined over the same period.

Catch rates were similar for brook trout, creek chubs and white suckers at both sites from 1983-1986. Common shiner catch rates were consistently higher at FCD than FEX, and burbot catch rates were consistently higher at FEX than FCD. These differences can be attributed to habitat differences between the sites. Overall, catch rates continued to be similar at both sites although more species showed a trend toward increasing catch rates at FEX.

Catch length. Mean length of most fish at FEX showed no trends from 1983-1986 (Table 7.8). Creek chubs showed a decline in mean size from 1984-86 and brook trout mean length declined in 1986. This indicates that the size structure is consistent from year to year within the fish community at FEX.

FCD also showed no consistent trend in mean length for any of the dominant fish species although a similar trend to FEX was seen in declining brook trout mean length in 1986 (Table 7.8). Brook trout, common shiners, creek chubs and white suckers were all significantly larger in mean length at FCD than FEX with the exception seen in burbot (TTest, $p<0.05$). Overall, the two sites were similar in mean length and in trends in mean length.

D. Fish Community Mobility

Most non-salmonid species with adequate sample sizes showed site to site movement as shown by the approximate equal number of fish marked in 1986 as 1985 although the recapture percentages were similar in most species except creek chubs which declined in recapture.

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Table 1.1

Table 1.1. A summary of the results of the analysis of the data from the 1980-1981 season. The table shows the number of cases of disease, the number of deaths, and the number of cases per 100,000 population.

Year	CCF	Deaths	Rate
1980	1.5	1	1.5
1981	1.5	1	1.5
1982	1.5	1	1.5
1983	1.5	1	1.5

Table 1.1

Mean and standard deviation of the
 100-year flood frequency at each of the four
 sites for September 1960 using a 10-year flood

Species

Age

1967

1971

1975

1978

1971

100-year flood	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Standard deviation	0.1	0.1	0.1	0.1	0.1	0.1	0.1
100-year flood	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Standard deviation	0.1	0.1	0.1	0.1	0.1	0.1	0.1
100-year flood	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Standard deviation	0.1	0.1	0.1	0.1	0.1	0.1	0.1

1971

100-year flood	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Standard deviation	0.1	0.1	0.1	0.1	0.1	0.1	0.1
100-year flood	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Standard deviation	0.1	0.1	0.1	0.1	0.1	0.1	0.1
100-year flood	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Standard deviation	0.1	0.1	0.1	0.1	0.1	0.1	0.1

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項目	1990年	1991年	1992年	1993年	1994年	1995年	1996年	1997年	1998年	1999年	2000年	2001年	2002年	2003年	2004年	2005年	2006年	2007年	2008年	2009年	2010年	2011年	2012年	2013年	2014年	2015年	2016年	2017年	2018年	2019年	2020年	2021年	2022年	2023年	2024年	2025年	2026年	2027年	2028年	2029年	2030年	2031年	2032年	2033年	2034年	2035年	2036年	2037年	2038年	2039年	2040年	2041年	2042年	2043年	2044年	2045年	2046年	2047年	2048年	2049年	2050年	2051年	2052年	2053年	2054年	2055年	2056年	2057年	2058年	2059年	2060年	2061年	2062年	2063年	2064年	2065年	2066年	2067年	2068年	2069年	2070年	2071年	2072年	2073年	2074年	2075年	2076年	2077年	2078年	2079年	2080年	2081年	2082年	2083年	2084年	2085年	2086年	2087年	2088年	2089年	2090年	2091年	2092年	2093年	2094年	2095年	2096年	2097年	2098年	2099年	2100年	2101年	2102年	2103年	2104年	2105年	2106年	2107年	2108年	2109年	2110年	2111年	2112年	2113年	2114年	2115年	2116年	2117年	2118年	2119年	2120年	2121年	2122年	2123年	2124年	2125年	2126年	2127年	2128年	2129年	2130年	2131年	2132年	2133年	2134年	2135年	2136年	2137年	2138年	2139年	2140年	2141年	2142年	2143年	2144年	2145年	2146年	2147年	2148年	2149年	2150年	2151年	2152年	2153年	2154年	2155年	2156年	2157年	2158年	2159年	2160年	2161年	2162年	2163年	2164年	2165年	2166年	2167年	2168年	2169年	2170年	2171年	2172年	2173年	2174年	2175年	2176年	2177年	2178年	2179年	2180年	2181年	2182年	2183年	2184年	2185年	2186年	2187年	2188年	2189年	2190年	2191年	2192年	2193年	2194年	2195年	2196年	2197年	2198年	2199年	2200年	2201年	2202年	2203年	2204年	2205年	2206年	2207年	2208年	2209年	2210年	2211年	2212年	2213年	2214年	2215年	2216年	2217年	2218年	2219年	2220年	2221年	2222年	2223年	2224年	2225年	2226年	2227年	2228年	2229年	2230年	2231年	2232年	2233年	2234年	2235年	2236年	2237年	2238年	2239年	2240年	2241年	2242年	2243年	2244年	2245年	2246年	2247年	2248年	2249年	2250年	2251年	2252年	2253年	2254年	2255年	2256年	2257年	2258年	2259年	2260年	2261年	2262年	2263年	2264年	2265年	2266年	2267年	2268年	2269年	2270年	2271年	2272年	2273年	2274年	2275年	2276年	2277年	2278年	2279年	2280年	2281年	2282年	2283年	2284年	2285年	2286年	2287年	2288年	2289年	2290年	2291年	2292年	2293年	2294年	2295年	2296年	2297年	2298年	2299年	2300年	2301年	2302年	2303年	2304年	2305年	2306年	2307年	2308年	2309年	2310年	2311年	2312年	2313年	2314年	2315年	2316年	2317年	2318年	2319年	2320年	2321年	2322年	2323年	2324年	2325年	2326年	2327年	2328年	2329年	2330年	2331年	2332年	2333年	2334年	2335年	2336年	2337年	2338年	2339年	2340年	2341年	2342年	2343年	2344年	2345年	2346年	2347年	2348年	2349年	2350年	2351年	2352年	2353年	2354年	2355年	2356年	2357年	2358年	2359年	2360年	2361年	2362年	2363年	2364年	2365年	2366年	2367年	2368年	2369年	2370年	2371年	2372年	2373年	2374年	2375年	2376年	2377年	2378年	2379年	2380年	2381年	2382年	2383年	2384年	2385年	2386年	2387年	2388年	2389年	2390年	2391年	2392年	2393年	2394年	2395年	2396年	2397年</
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prior years. Size to size movement indicated for common shiners and creek chubs by 12 of 12 and 12 of 12 respectively. In 1980 both populations. White suckers and northern pike showed movement in size to size movement of 10 of 12 and 10 of 12 respectively. In 1981 both populations showed movement in 1980 and 1981 were similar for both species but showed more differences in 1980 which may be attributable to the high-fishing lower classings in 1980 than in the previous two years. (Standard 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100). No fish were found to have more than 1 scale (or less) in difference in 1980. Overall, size to size movement was lower in 1980 than in previous years.

2. Individual Species Analysis

Introduction. Growth and condition of fish can be important indicators of a stressor in the environment of the fish. To learn about stress species common shiners, creek chub, white suckers and northern pike are important species in this community to monitor the potential effects of the EIS project on these two populations. Growth data is reported on in element 3.

Age and Growth. Preliminary age and growth analysis of common shiners, creek chub, northern pike and white suckers are reported in Table 1.1. All analyses were done using scales and the length-weight relationship was calculated using the technique outlined in Mills and Taylor (1987). Back-calculation of length was done using the annual technique in Federal and Clark (1978).

Common shiners exhibited better than average growth in the Ford River when compared to literature data in these species through fourth years (Clark 1980). The first year growth is similar to that found in the literature. Low's phenomenon is seen in all years which may reflect the selectivity of our sampling or differential mortality of different sizes of common shiners.

Creek chub growth in the Ford River is also above the average growth rate in the literature in all years (Clark 1980). No Low's phenomenon was seen in any year class. Three year old fish had the best growth rates of the four years reported.

Both white suckers and northern pike showed below average growth rates in the Ford River through all the age classes reported when compared to literature values (Clark 1980). Low's phenomenon was seen in white suckers with the age 4 fish having the best growth rates of the four years examined.

Age and growth analysis is nearly complete on the 1980-1981 fish and statistical comparisons to literature data and between years will be completed then. Additional analysis will include analysis of seasonal growth increment and yearly growth increment, and an examination of the effect population size using ODE and other factors on growth. These analyses should allow us to separate the environmental and density-dependent factors from the EIS effects in the examination of growth.

Condition. Fish condition factors for common shiners, creek chubs and white suckers were performed using relative weight (Wr) condition factors as described in Wade and Anderson (1978). Standard weight formulas were calculated from 3 literature populations for common shiners, 5 literature populations for creek chubs and 12 literature

Table 7.10

Mean and standard deviation of the number of children per woman in 1960

Source

U.S. Census Bureau, 1960

	Age	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Unmarried women	15-19	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
	20-24	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
	25-29	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
	30-34	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
Married women	15-19	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
	20-24	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
	25-29	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
	30-34	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
Total women	15-19	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
	20-24	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
	25-29	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
	30-34	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0

populations for white suckers using the 1965 population growth equation in 1966 and 1967. The 1965 equation was then applied to the standard weights and given a 10% value based on the 1965 standard weight/100 = 100. The values for 1966 and 1967 were based on the 1965 standard weight and given a 10% value based on the 1965 standard weight. The 1965 equation was then applied to the standard weights and given a 10% value based on the 1965 standard weight. The 1965 equation was then applied to the standard weights and given a 10% value based on the 1965 standard weight.

The 1965 equation for white suckers, common shiners and white suckers are as follows:

Common shiners $\log W = 1.25 \log T + 0.0001 \log T^2 - 0.0001 \log T^3$
 White suckers $\log W = 1.25 \log T + 0.0001 \log T^2 - 0.0001 \log T^3$

Constitution factors for common shiners and white suckers were based on the equation given by Fann 1965, assuming the highly variable growth rates in the past. The 1965 equation was then applied to the standard weights and given a 10% value based on the 1965 standard weight. The 1965 equation was then applied to the standard weights and given a 10% value based on the 1965 standard weight. The 1965 equation was then applied to the standard weights and given a 10% value based on the 1965 standard weight.

Future Analysis

The information to our study that we have presented in this report is an analysis of fish community size structure which will be reported in an upcoming report.

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CHAPTER 2 - BROOK TROUT MANAGEMENT

Changes from Synopses - None

Objectives

The overall objective of this chapter is to describe the effects of the Navy's ELF project on brook trout Salvelinus fontinalis. Brook trout are well known to be sensitive to chemical changes and exposed to have to avoid suboptimal conditions in the food chain as shown previously. Any changes by ELF could cause adverse physiological problems. The specific objectives of this chapter are to determine: 1) The chemical pattern and magnitude of brook trout movement through the ELF corridor; 2) The rates of movement through the ELF corridor of brook trout; 3) The population for those movements and 4) The age growth and condition of brook trout in the food chain.

Materials and Methods

The sites and gear used in this chapter were previously described in chapter 1. All brook trout were captured on a daily basis from the traps and transported with special ice storage facilities to the lab. All traps were constructed by the lab and 2, 4, 6, 8, and 10 ft. traps were used. All traps were constructed, measured and weighed. A subsample of fish was taken tagged using otolith tags on the adipose or were coded by the techniques described in Synopses and Theory 1981. The fish were then determined that a control group had the least catch per trap and that this method had high survival and retention over a 12 hour period. All fish were specific for age and if needed or additional data to examine tag catch loss. All fish were released upstream or downstream from the site in the direction of normal flow a minimum period.

Data analysis concerning the role of physical and chemical factors on brook trout movement of 1981 and 1982 was done using and an analyzing data. Physical and chemical data of 1981 and 1982 was collected by the fisheries staff from 1981-82. There was no data from a calibrated staff group of 1981 and 1982 or a daily basis. Temperature data was collected continuously using a calibrated water thermometer at 19 and 21. Chemical data of 1981 and 1982 was collected on a bi-weekly basis at 19 and 21 using standard methods and is summarized in Table 2.1.

Results and Discussion

A. Marking Statistics

Numbers of fish tagged declined from a high of 224 in 1981 to 12 in 1986 because of a lack of fish caught in our gear (Table 2.2). The between site recapture rate was consistent in 1981 and 1982 and fell to 0% in 1986. Tagging mortality averaged 5.4% from 1981 to 1986 which is probably an underestimate because we are only examining fish which float back into nets and fish that we find on regular samples of the study area. The percentage of angler returns also declined from 12% in 1984 to 0% in 1986 which probably reflects the decrease in the total number of fish individually tagged and the amount of angler effort.

Table B.1 water quality data from 1983-1986 at Two Mile
Creek and FCO.

Parameter	Site	
	TW	FCO
DO	9.3	9.9
pH	7.5	7.6
Alkalinity (CaCO ₃)	182.6	188.2
Hardness (CaCO ₃)	182.6	188.2
Dissolved Solids	182.6	188.2
Conductivity	182.6	188.2

Table 8.2 Brook trout marking and recapture summary for FEX and FCD for 1984 - 1986.

Year	Tag Summary	Site	
		FEX	FCD
1984	Number Tagged	71	243
	Number Fin Clipped	48	37
	Percent Tag Recapture	16.7%	
	Estimated Tagging Mortality	5.7%	
	Percent Angler Recapture	12.1%	
1985	Number Tagged	45	81
	Number Fin Clipped	38	53
	Percent Tag Recapture	14.3%	
	Estimated Tagging Mortality	8.7%	
	Percent Angler Recapture	3.0%	
1986	Number Tagged	15	40
	Number Branded	19	8
	Number Fin Clipped	58	32
	Percent Tag Recapture	0.0%	
	Estimated Tagging Mortality	3.4%	
	Percent Angler Recapture	3.0%	

B. Brook Trout Catch Patterns

Brook trout catches peaked in the spring and summer at all sites except FCB. Since catch patterns were similar at all sites, data will be presented from FCB as example data in this report. Figure 8.1 shows that in 1984, the mean daily catch was at its maximum in the first week of June at 15.8 brook trout collected per day with the high catch pattern continuing for three weeks. A similar pattern was seen in 1985 although delayed by one month until the first week of July when 10.7 brook trout per day were collected and this continued for only one week post-catch. Catch rates decrease rapidly after this week to between 1 and 2 fish per day. This pattern did not continue in 1986. Catch rates were highest in May and June in 1986 than later in the year but the peak catch rates of 1984 and 1985 were not repeated. Movement in the garden was much higher than the downstream movement at all years at all sites (Mann-Whitney U Test, $p < 0.05$). In summary, the data showed a consistent upstream movement pattern in the spring and summer of all sampling years although the intensity and timing varied from year to year.

The 1985 annual report discussed in detail the relationship between temperature and movement in 1984 and 1985. This movement was not repeated in 1986 although temperatures did exceed 18°C which is the optimal growth temperature for brook trout. An analysis of the pattern of water temperatures for each year shows that temperatures in 1984 and 1985 rose rapidly and remained high (Figure 8.2). Water temperatures in 1986 although not significantly different from 1985, increased more slowly with multiple comparisons, $p < 0.05$, demonstrated a significant $p < 0.05$ gradual increase in the two years. This indicates that the duration of high water temperatures and the acclimation time to those temperatures may also play important roles in determining whether the brook trout move to more suitable habitats. Additional analysis of this trend is in progress and will be reported on in a future report.

Two additional factors, although not significant in the 1985 analysis of factors, which influence this movement were discharge and population size. The spring drought created extremely low water conditions in 1986. Comparisons between years show that 1986 had significantly lower discharge than the previous years (Friedman's Test with multiple comparisons, $p < 0.05$) and is illustrated in Figure 8.3. These low water conditions coupled with poor groundwater inputs to the river from low spring precipitation may have created a thermal barrier to this movement. Low densities of brook trout may have also contributed to the lack of movement by allowing those first targeted by high temperatures to find available cold water groundwater refugia without competition from other salmonids. Additional analyses examining these factors are currently in progress and will be discussed in a future report.

C. Brook Trout Movement Characteristics

The brook trout moved from FCB and FCB upstream to the TW site on Two Mile Creek based on both year recapture and usable anchor data (Table 8.3). Only one fish was recaptured at FCB in three sampling

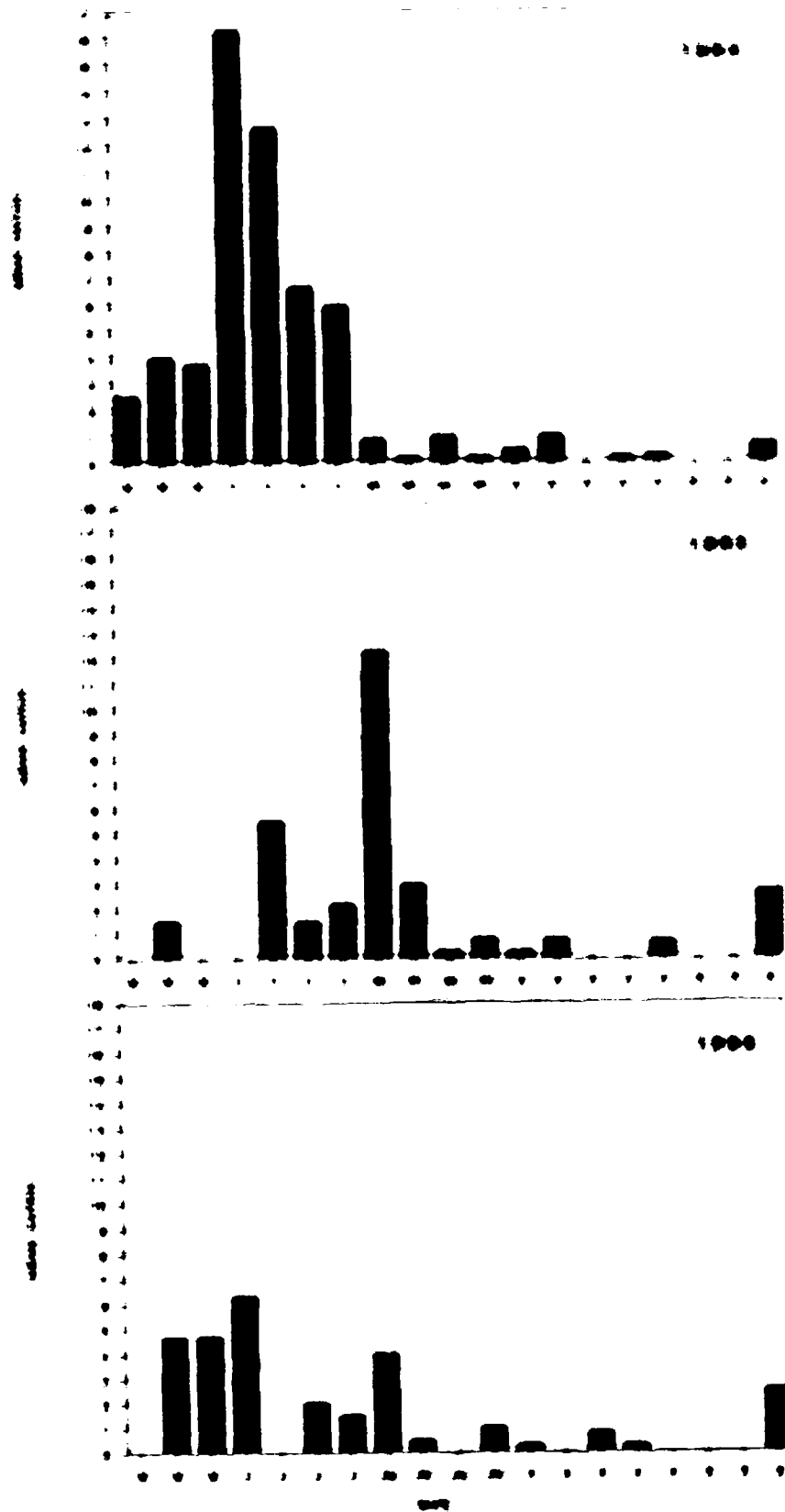


Figure 8.1 Mean daily catch of brook trout plotted on a weekly basis at FGD from 1984 to 1986

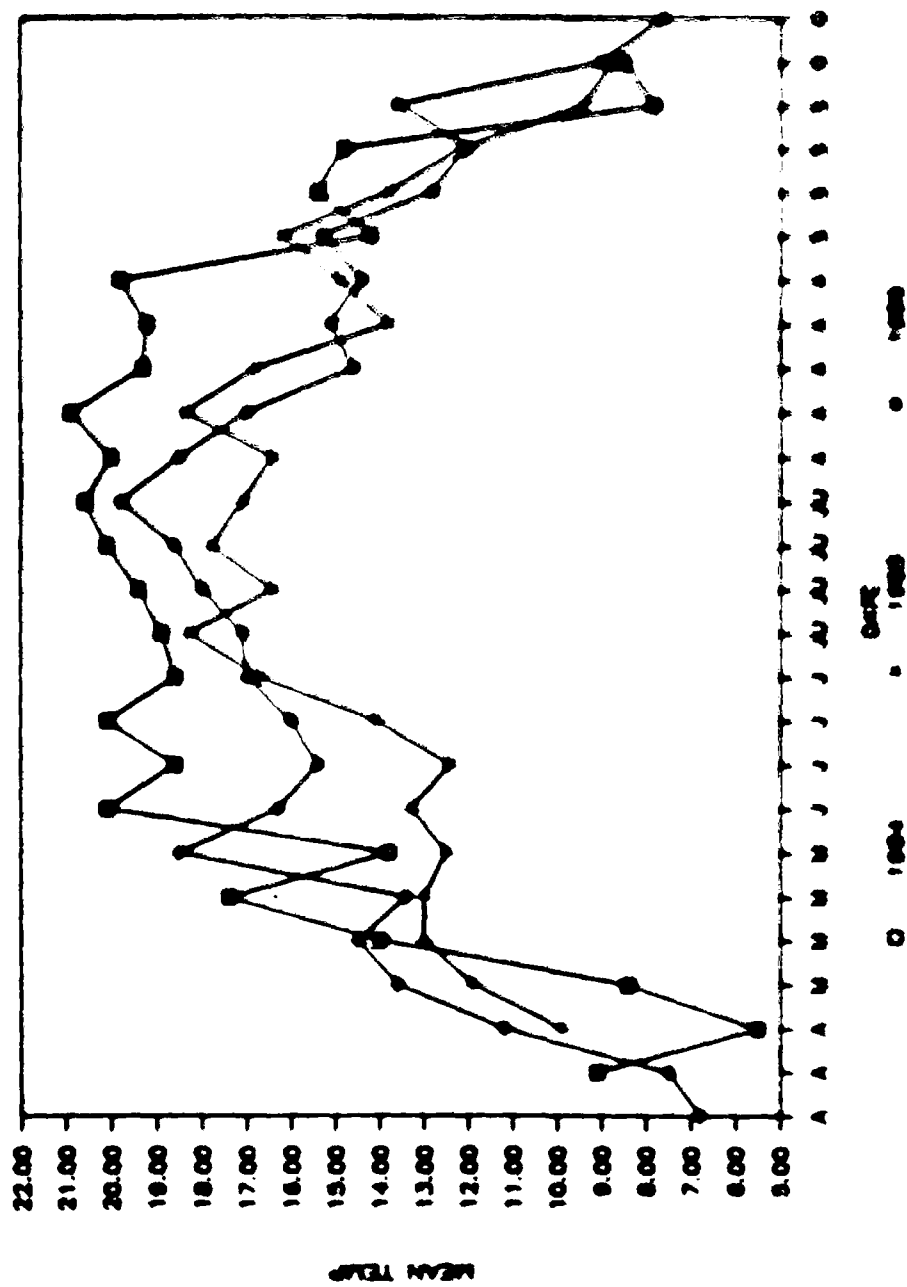


Figure 8.2. Mean daily temperature (°C) plotted on a monthly basis for two years, 1984 and 1985.

MEAN AMBIENT DISCHARGE

FOR 1983-1986

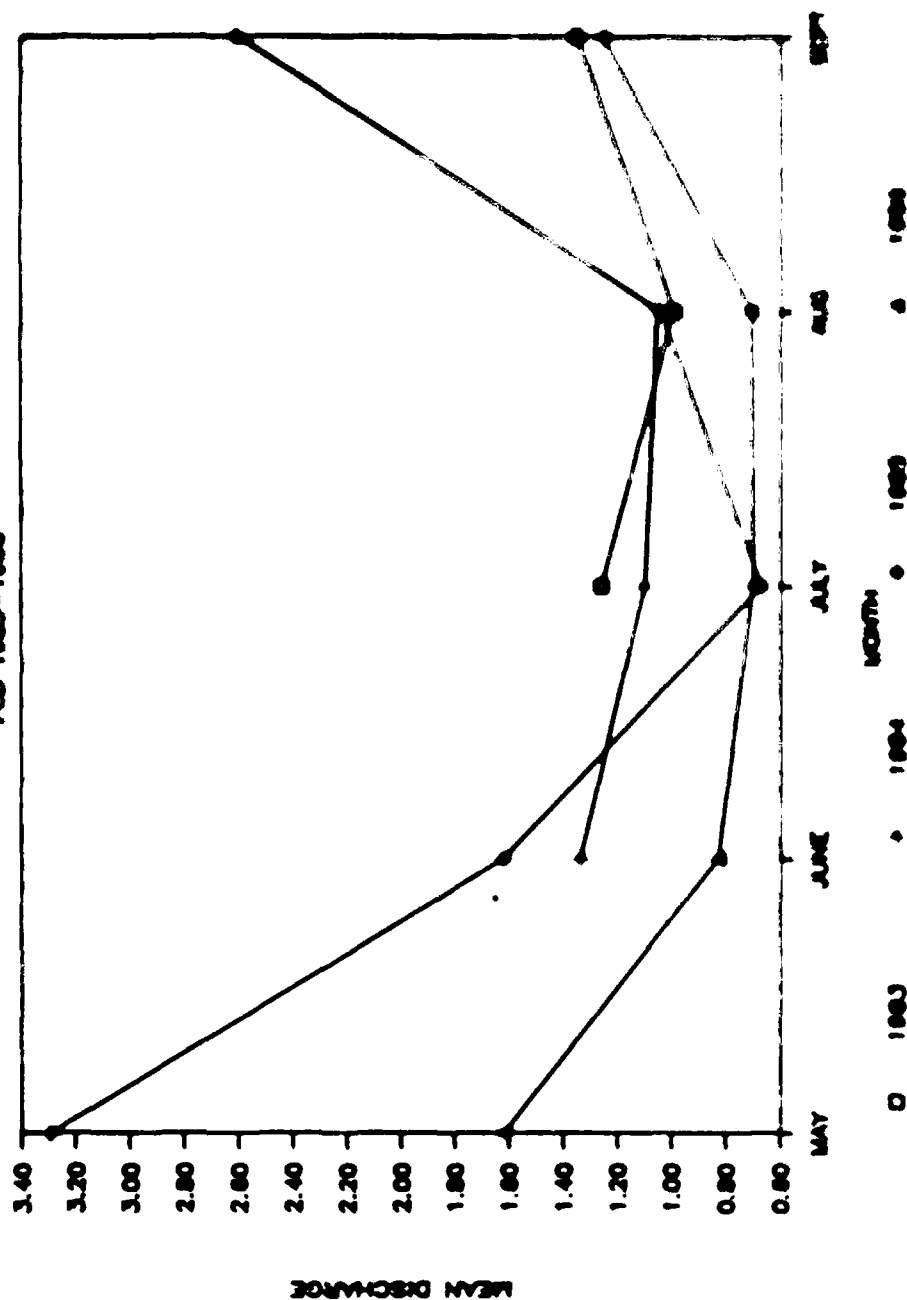


Figure 8.3. Mean monthly discharge (M³/sec) at RFD from 1983 to 1986

Table 8.3 Brook trout movement rate summary for 1984 - 1986.

Year	Recaptured type	Site Marked to		Distance (km)	n	Mean rate	
		Site Recaptured	Site Recaptured			(km/day)	Rate (km/day)
1984	Recaptured fish	FLB - IM	FLB - IM	12.7	11	1.6	1.7
		FLB - IM	FLB - IM	26.0	39	2.9	2.9
		FLB - FLB	FLB - FLB	10.1	7	2.7	2.8
	Angler Returns	FLB	FLB	7.0	1	2.5	
		FLB	FLB	10.0	10	2.0	1.9
1985	Recaptured fish	FLB - IM	FLB - IM	12.7	7	1.6	1.1
		FLB - IM	FLB - IM	26.0	6	3.0	2.7
		FLB - FLB	FLB - FLB	10.1	3	1.7	1.3
	Angler Returns	FLB	FLB	0.7	3	1.1	1.0
		FLB	FLB	0.7	3	1.1	1.0
1986	No Recaptures or Angler Returns						

seasons. No downstream movement from Two Mile Creek was found through November 1984 and through September 1985 or 1986. Three tag loss fish from the TM site in 1984 were collected in 1985 at FCD, thus some return movements occurred between winter and early spring. The length of the brook trout that made this movement was significantly greater for fish above 190 mm than those below 190 mm (Chi-Square Test, $p < 0.05$). Only six clipped fish under 190 mm were captured at TM in 1984 and no clipped fish under 190 mm were collected in 1985 or 1986.

Optimal growth temperatures also appeared to be responsible for the movement up Two Mile Creek instead of continuing up the Ford River. Groundwater inputs kept TM at or near 16 C in all three years (Figure 8.4) although reduced groundwater inputs (Figure 8.5) did force temperatures higher in 1986 than in previous years. FCD exceeded the temperatures in TM in each field season thus the fish "chose" the tributary that they could maintain better growth and survival in.

D. Brook Trout Movement Rates

Brook trout were found to move at mean rates of between 1.1 to 5.0 km/day (Table 8.3). Fish moving from FEX to TM (12.7 km) moved at similar rates from 1.4 to 1.6 km/day in 1984 and 1985. No movement was found between FEX and TM in 1986. Movement from FCD to TM (26.8 km) occurred at different mean rates in 1984 (2.9 km/day) than in 1985 (5.0 km/day). No movement was found between FCD and TM in 1986. Brook trout that were moving between FCD and FEX (14.1 km) also moved at different rates in the first two sampling years with rates of 2.7 km/day in 1984 and 1.2 km/day in 1985. No movement was found between FCD and FEX in 1986. Angler tag return data from throughout the Ford River verified the above trends and indicated that brook trout move at steady pace (1984 - 2.4 km/day, 1985 - 1.1 km/day and no reports in 1986) upstream similar to rates recorded from our sampling gear.

E. MI DNR Population Analysis

Michigan Department of Natural Resources conducted four brook trout population surveys in 1985 and 1986 using 220 V DC electrofishing gear. Two sites were used in this analysis: 1) Ford Site 1 which is 5 km upstream from FEX; and 2) A site approximately 1 km upstream from FCD. Both sites were approximately 1000 m in length and 1 ha in area. A single Peterson mark-recapture estimate was done at each site to determine trout densities.

Ford Site 1 was found to have 269 ± 47.5 fish per ha on June 25, 1985. The total biomass of this population was estimated from length frequency and length-weight data to be 2.35 kg/ha. The length frequency of this site showed that this area is mainly by young of the year fish with very low densities of adult and juvenile fish (Figure 8.6).

Surveys of brook trout populations at the site near FCD showed very low densities of fish. Only 18 fish were caught on the marking run on June 27, 1985, 5 fish on the marking run on August 20, 1985 and 0 fish on the marking run on August 21, 1986. Population estimates were made from the one marking run by assuming that the catch efficiency of each size class was the same at both sites. Densities on June 27, 1985 were estimated at 60.7 fish/ha at FCD with a biomass of 1.28 kg/ha. The length frequency of the catch at this date shows very low densities of

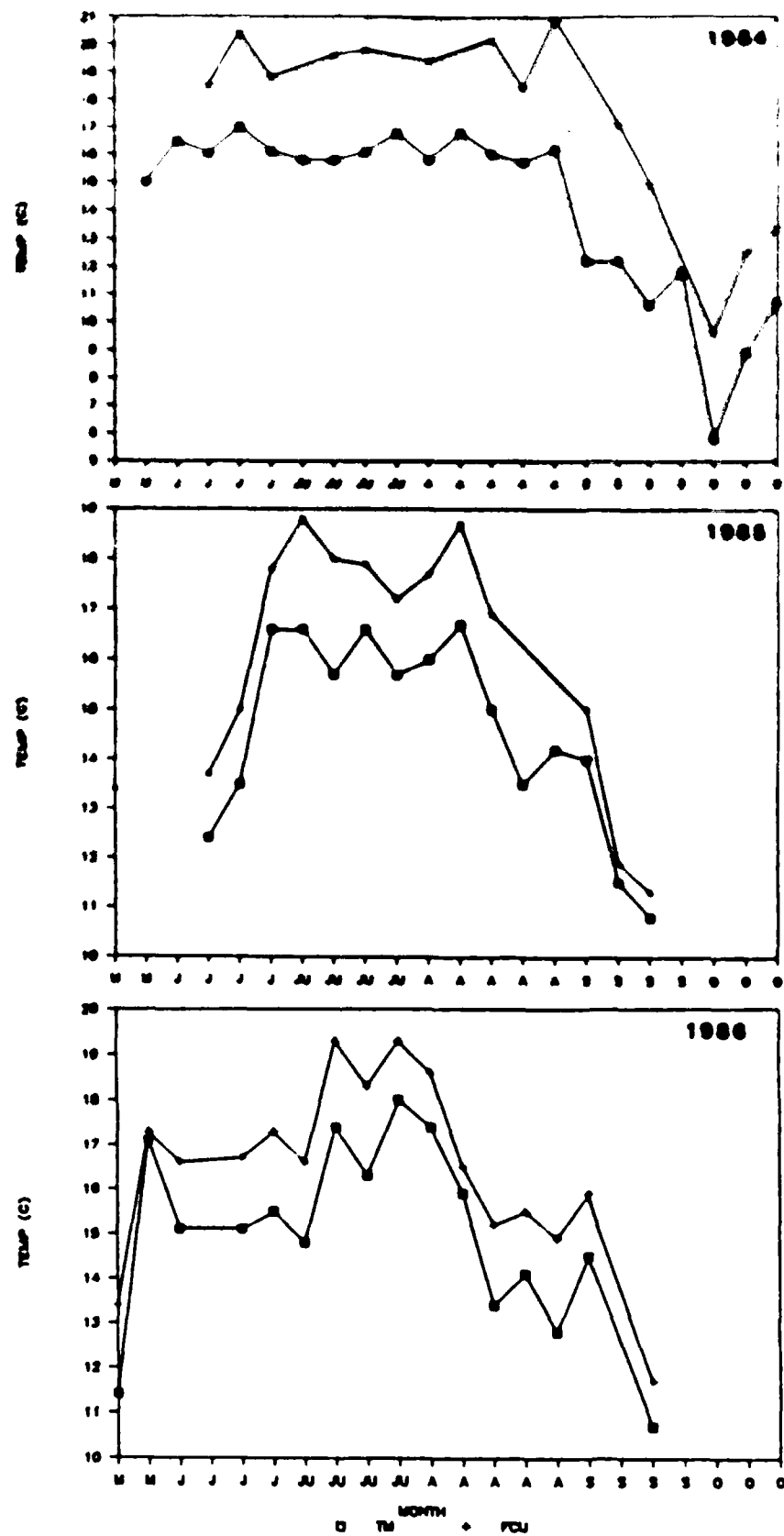


Figure 8.4. Mean daily temperature (C) plotted on a weekly basis at TM (boxes) and FCU (crosses) from 1984 to 1986.

MEAN MONTHLY DISCHARGE

TM 1904-1905

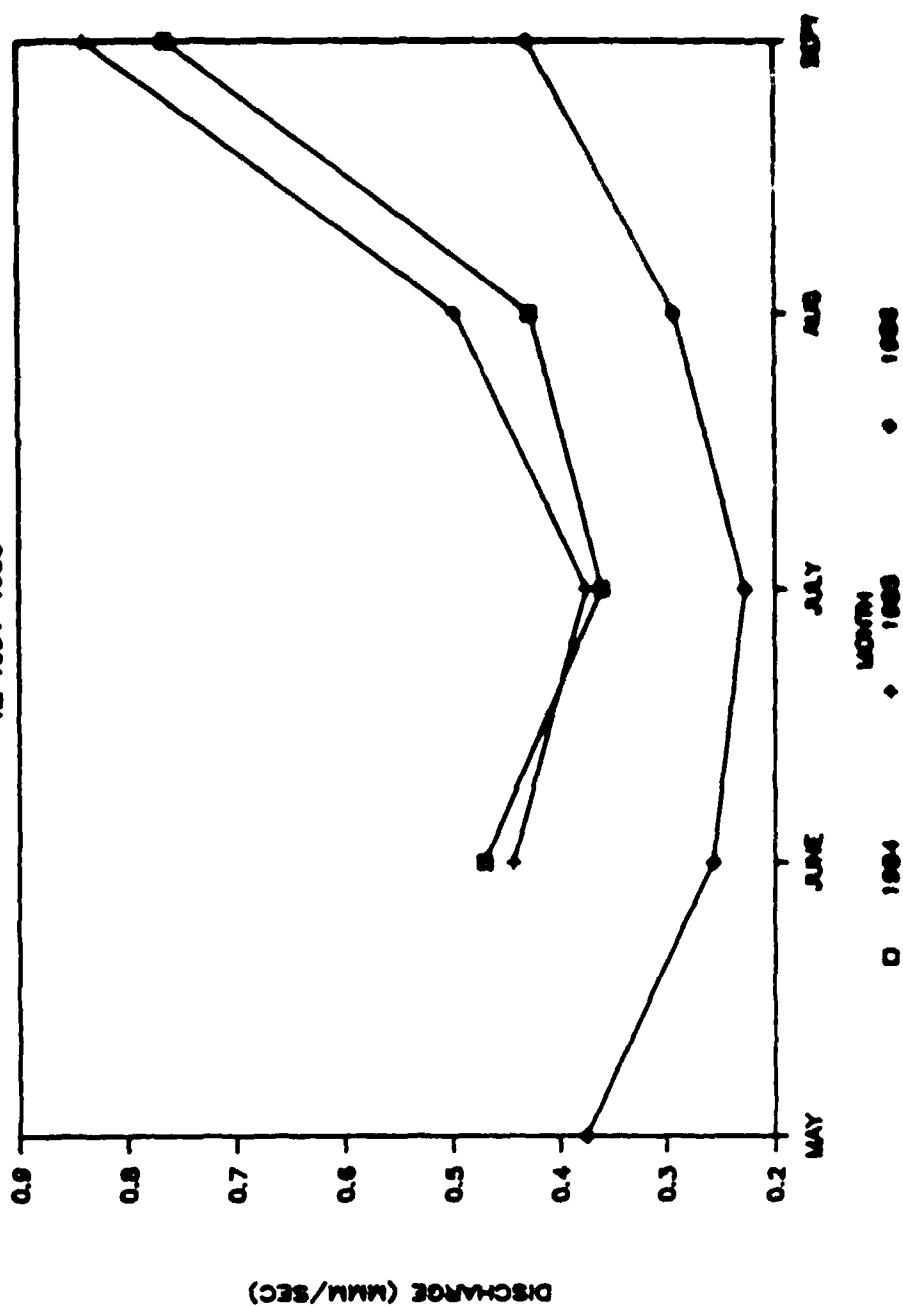


Figure 8.5. Mean monthly discharge (M^3/sec) at W from 1904 to 1905

FORD SITE 1 - 6-25-85

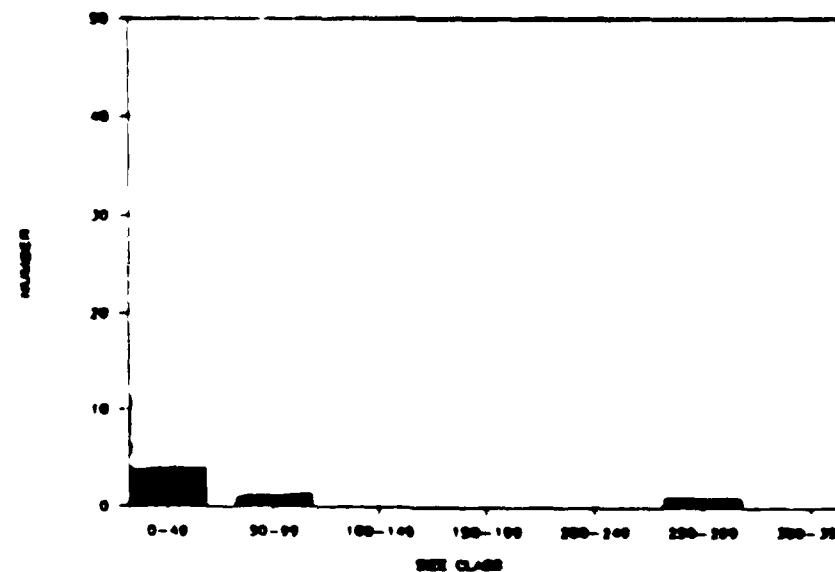
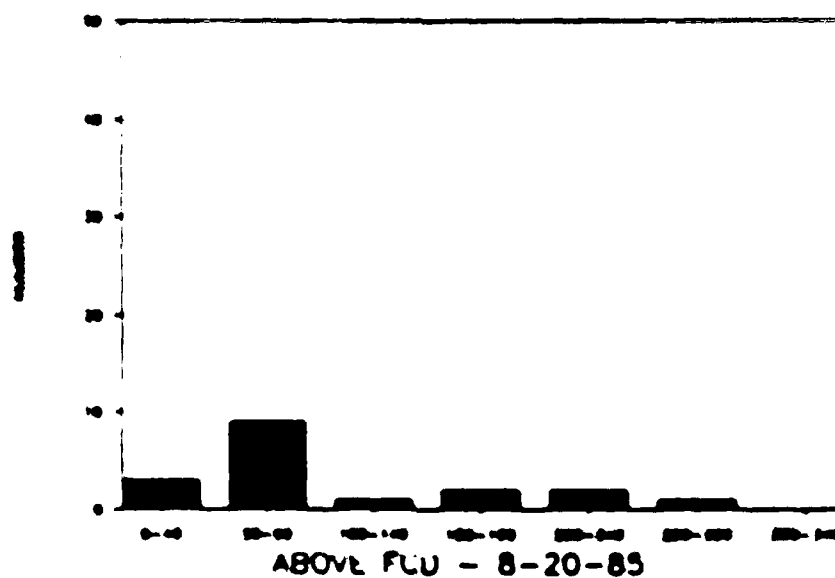
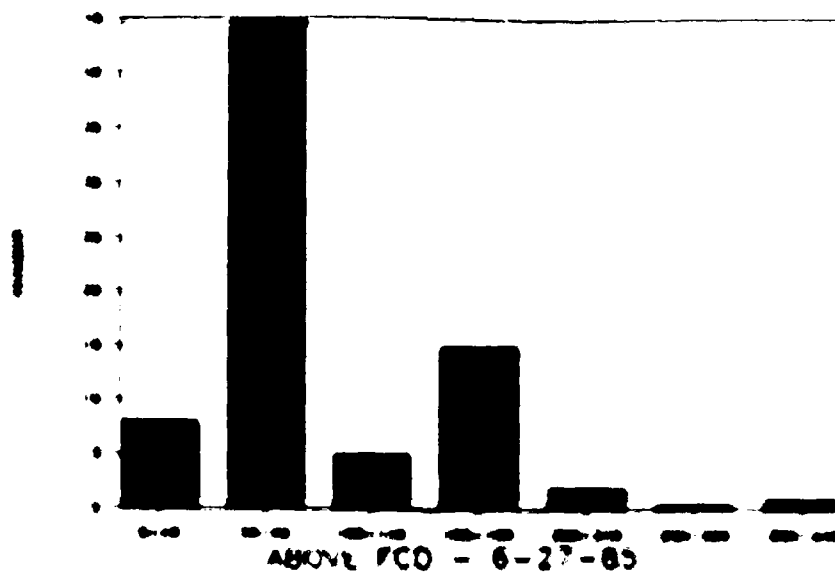


Figure 8.6. Brook trout length frequencies from Michigan Department of Natural Resources electrofishing surveys of the Ford River in 1985.

YOY and adult fish at the site (Figure 8.6). The population estimate in the post-movement sampling date of August 21, 1985 was 107 fish, 76 with a biomass of 0.31 kg/ha. Only a few young of the year remained at this site in August (Figure 8.6). No fish were captured in August 1986.

These preliminary data indicate that most brook trout move out of the lower site in the summer and are at low densities through out the river. These densities are very low when compared to literature studies of brook trout populations and are probably indicative of the variable abiotic conditions in the Ford River. Surveys will be completed at the above sites and two additional sites using land electrofishing (DC DB) and snorkeling (DC) techniques in the coming year to provide additional baseline population data and habitat usage. Additionally this data will determine what percentage of the population moves in the Ford River.

F. Brook Trout Age and Growth

Age and growth analysis on brook trout was completed using fish captured in the fyke nets and weirs. Data for all sites was pooled because of the high amount of mobility brook trout display in the Ford River. Age determination was done using scales. The body-scale relationship was determined using the technique described in Shupe and Taylor (1987). Backcalculations were made using the Finney technique described in Baginval and Tesch (1978). This preliminary data covers only fish from 1983 and 1984, the 1985 and 1986 analysis are currently in progress.

Ford River brook trout show excellent growth as seen in Table 8.4 when compared to populations described in Carlander (1969). Size at annulus formation was consistent in the 1983 and 1984 samples. Late phenomena was seen not in either year. Statistical analysis of yearly differences and comparisons to the literature will be made when all samples are completed. Analysis of abiotic and density dependent effects will also be completed at that time.

G. Brook Trout Condition

Examination of brook trout condition was made using the relative weight methodology as described in element 7. The standard weight formula: $\log wt = -5.085 + 3.043 \log tl$ ($r=0.999$) was determined using the 50th percentile equation from 45 literature populations.

Brook trout relative weight ranged from average to slightly below average the species average from 1983 to 1986 (Figure 8.7). Relative weight values declined from 101.6 in 1983 to 89.0 in 1986. Low water conditions, above optimal temperatures and poor groundwater inputs may have caused the decline from the 1984 to 1985 values to the low 1986 values. Statistical analysis of this data is in progress and will be reported on in an upcoming report.

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Table 8.4 Backcalculated length at annulus data for brook trout from 1983-1984.

Year	Age Class	Backcalculated Length at Annulus	
		1	2
1983	1	94 ± 21.3 (97)	
	2	81 ± 17.6 (26)	190 ± 27.4 (26)
	3	97 ± 43.0 (4)	187 ± 42.9 (4)
	Overall		283 ± 47.4 (4)
	Mean	92 ± 22.0 (127)	190 ± 26.9 (30)
1984	1	102 ± 19.9 (30)	
	2	90 ± 17.8 (28)	193 ± 26.4 (30)
	3	144 ± 7.2 (2)	263 ± 12.4 (2)
	Overall		283 ± 47.4 (4)
	Mean	97 ± 21.3 (60)	198 ± 26.9 (30)

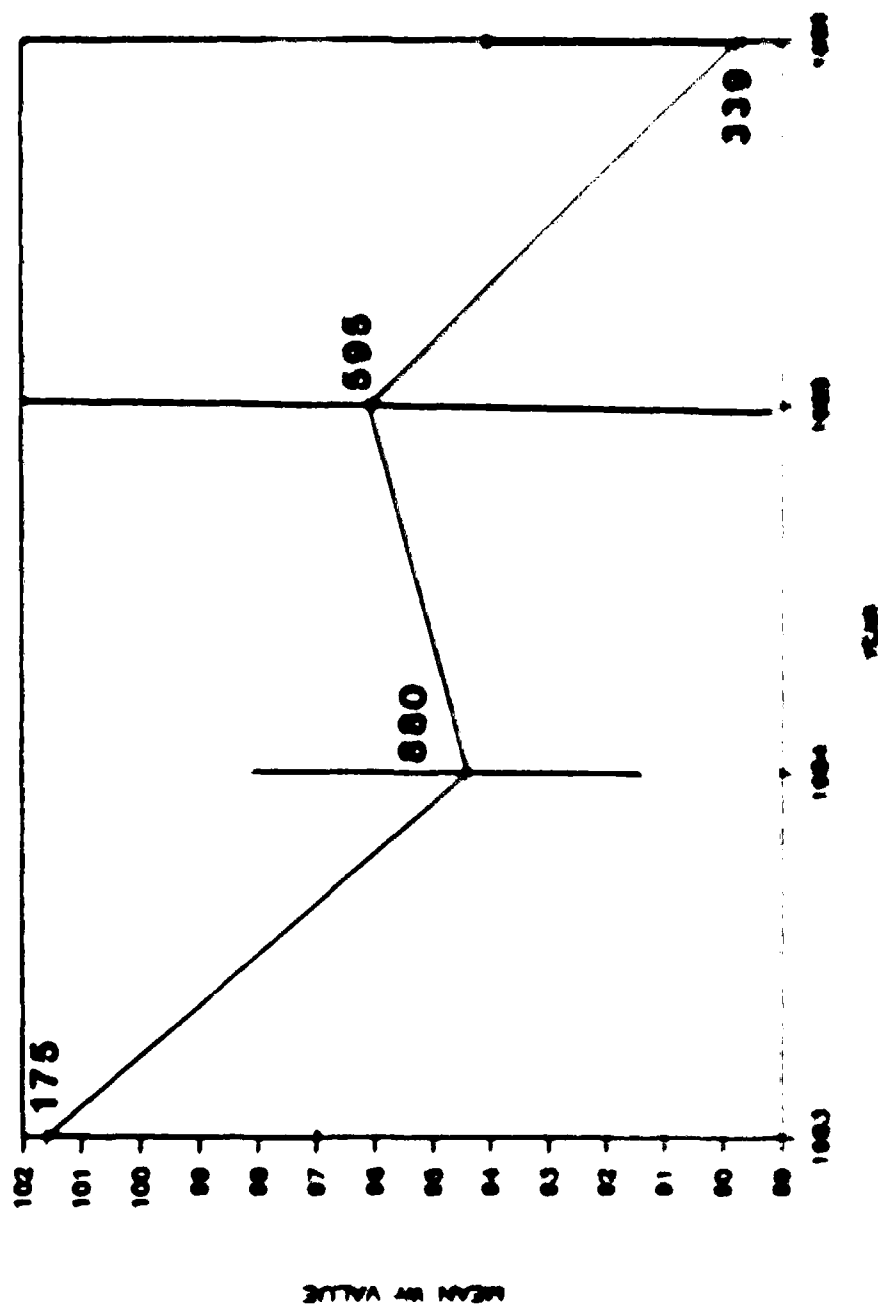


Figure 17. Brook trout mean (\pm SD) yearly Wt values from the first three. Numbers at points refer to sample size used in calculation.

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Element 9 - Parasite Loads of Selected Fish Species

Changes from Work Plan - Selected fish species are the longnose dace, Rhinichthys cataractae (Family: Cyprinidae) and mottled sculpin, Cottus bairdi (Family: Cottidae).

Objectives

1) To establish a taxonomic base of parasitic species that infect longnose dace and mottled sculpins. 2) To calculate the infection rates (prevalence and mean number) of parasites of these two fish species collected at each site. 3) To statistically analyze the data to determine if relationships exist between parasite infection rates and fish sex, age (length), as well as to determine if differences in parasite infection rates exist between sites, seasons, and years.

Material and Methods

Nine hundred twenty-nine mottled sculpins (244 from FCU, 141 from FEX, 144 from FCD) were collected by kick sampling with a 1/8" mesh minnow seine and fyke netting from May 1981 through October 1986. One thousand one hundred-fifteen longnose dace (277 from FCU, 417 from FEX, 421 from FCD) were also collected from May 1981 through October 1986. At the collecting site, fishes were killed in 10% formalin; a slit was then made from the vent anterior to the isthmus area of the fish to preserve the viscera. After this, fishes were preserved in 10% formalin, individually packaged by Kapak heat sealable pouches, and sent to MSU.

At necropsy, a fish specimen accession number was formulated and the weight, total length, and sex of each fish were recorded and scales or otoliths were taken for age determination. Fishes were examined for external parasites before the abdominal cavity was opened. The muscle, eyes, brain, gills, liver, gall bladder, kidney, urinary bladder, gonads, and the digestive tract were placed in petri dishes and examined with a dissecting microscope and/or compound microscope.

Trematodes and cestodes recovered were processed by several techniques and stained with Mayer's Alum Carmalum, Grenacher's Alcoholic Borax-Carmine, and Lynch's Precipitated Method using Grenacher's Alcoholic Borax-Carmine (Mayer and Pether, 1958). Nematodes were cleared in glycerin and examined in temporary mounts. Parasites were identified to genus according to Hoffman (1967), Schell (1970), Scheldt (1971), and Janney (1961, 1963, 1971). Species were determined, wherever possible, by reference to the original description within a genus. I thank Dr. Charles H. Peebles, Department of Natural Science, MSU, for his help in identifying some of the parasites.

Prevalence is the percentage of fish infected and mean number is the mean number of worms per infected fish in a given sample. The prevalence and/or mean number of each parasite species occurring in sculpins and dace were calculated by sex. However, because of nonsignificant differences in prevalence and mean number for the parasite species, the parasitological data were combined, irrespective of host sex. The prevalence and/or mean number of each parasite species from sculpins and dace were graphed seasonally to identify infection trends over time. Since trends were not apparent and due to the extreme variation in monthly and seasonal mean numbers, the data for the three most common helminth species of both dace and sculpins will be analyzed by dace and sculpin age cohorts as they become older between seasons. Chi-square analysis, Kruskal-Wallis Test, and the Mann-Whitney U Test were used to determine if the prevalence and/or mean number of each parasite species significantly differed between fish age cohort, sex, site, and season. Diversity values for the helminth communities in dace and sculpins were calculated using Brillouin's index since the helminth community within a fish is a fully censused population and evenness values were calculated using the formula $H' = H/\log sp.$ for fully censused populations (Pielou, 1975). The calculations of diversity and evenness values included helminths found in the gut and other helminths (primarily larval trematodes) found in other places in and on the fish host. Monogenetic trematodes were not included in the calculations.

Results and Discussion - Longnose Dace

The parasite faunas of longnose dace from the three sites are in Tables 9.1, 9.2, and 9.3. One thousand

ninety-nine (98.6) of the 1,115 dace examined were infected with at least one parasite species. Twelve parasite species (1 Monogenea, 2 Digenea, 2 Cestoda, 2 Nematoda, 1 Acanthocephala, 3 Protozoa) were recovered. The number of parasite species found between sites (FCU-11, FEX-12, FCD-11) and the number of helminth species whose individuals were counted (FCU-7, FEX-8, FCD-7) were similar. Gyrodactylus sp., Epistylis sp., Myxobolus sp., and Trichodina sp. infected the gills. Ligula intestinalis occurred in the hemocoel while Neascus sp. infected the integument, muscle, and the area between the branchiostegal rays and fins. Posthodiplosomus s. minimus occurred in the gonads, kidney, liver, and mesenteries. Raphidascaris acus, Mapionema hamulatus, Cystidicolidoides tenuissimus, Rhabdochona canadensis, and Neoechinorhynchus sp. were found in the intestine. Of the helminths found, only Gyrodactylus sp. and R. canadensis obtain maturity on and in dace, respectively, indicating that the helminth fauna of dace at each site is made up of larval parasites. Ligula intestinalis occurred as larvae (plerocercoids), while Neascus sp. and P. s. minimus occurred as metacercariae.

Gyrodactylus sp., Ligula intestinalis, Proteocephalus sp., C. tenuissimus, M. hamulatus, R. acus, Neoechinorhynchus sp., and Myxobolus sp. were infrequent in their occurrence and/or had low mean numbers. Epistylis sp. had the highest prevalence of the external parasites found on dace at each site. The prevalence of Epistylis sp. increased on dace from the upriver to the downriver sites.

The helminth fauna of dace from each site, made up of those species whose individuals were counted, are primarily composed of P. s. minimus, followed by Neascus sp., and then R. canadensis indicating that the helminth faunas are similar between sites. These results are similar to those of Fischthal (1953), who found that Neascus sp. and P. s. minimus were the most common parasites encountered in stream fishes.

Comparisons of the mean numbers (Tables 1, 2, 3) of P. s. minimus and Neascus sp. between sites for the total sampling period show that dace from FCU had significantly higher mean numbers than dace from FCD. Dace infected with P. s. minimus from FCU and FEX had significantly larger mean total lengths than dace from FCD. Dace from FCU had a

higher mean number of B. canadensis than dace from FEX and FCD; although the differences were not significant. There were no significant differences in the mean total lengths of dace infected with Neascus sp. and B. canadensis between sites. Both the prevalence and mean number of P. m. minimum, Neascus sp., and B. canadensis decreased from the upriver to the downriver sites. Greater infection levels of these parasite species in dace from FCU to the downriver sites likely result from the higher productivity with accompanying algal growth observed there. It is apparent that FCU has a greater nutrient load due to some organic enrichment from Channing, Michigan, and from non-point sources (cattle grazing and a mink farm). Also the bottom substrate differs between sites with cobble-gravel at FCU, gravel-sand at FEX, and mostly sand at FCD. A combination of this nutrient enrichment which increases productivity and cobble-gravel substrate at FCU presumably increases the number of snails that serve as intermediate host for P. m. minimum and Neascus sp. and increases the number of mayfly larvae that serve as intermediate hosts for B. canadensis. This tends to favor high infection levels in dace. The transitional decrease and lower infection levels observed at FEX and FCD are presumably due to the lessened effect of effluents and lack of substrate heterogeneity. Vinikour (1977) reported that longnose dace infected with Neascus rhinichthysi from one river with greater nutrient loads had significantly greater infection levels than dace collected from another river with lower nutrient loads.

Correlation coefficients between the total length of infected dace and the number of P. m. minimum, Neascus sp., and B. canadensis are all significant and are in Table 9.4. The increase in the number of Neascus sp. and P. m. minimum metacercariae with an increase in dace length may depend on a longer exposure time to parasitism, since body length is generally determined by age, and/or changes in the behavior of dace. The increase in B. canadensis in dace can be explained by the fact that as dace become larger (older), they eat more mayfly larvae, which serve as the intermediate hosts for B. canadensis (Hoffman, 1967).

The mean Brillouin's diversity indices and mean evenness values for dace infected with helminths are in Table 9.5. Mean helminth diversity was highest in dace from FCU in all four years; overall mean helminth diversity was also highest in dace from this locality. The mean helminth diversity decreased in dace from the upriver to the downriver sites in 1984, 1985, 1986, and when the data

was combined. Mean helminth diversity was lowest in 1983 when compared to the other years at all sites and increased in date from 1983 through 1986 at FEX and FCD. Generally, evenness values followed the patterns mentioned above.

Results and Discussion - Mottled Sculpins

The parasite fauna of mottled sculpins from FCU, FEX, and FCD are in Tables 9.6, 9.7 and 9.8. Overall, 926 (99.7%) of the 929 sculpins examined were infected with at least one parasite species. Fifteen parasite species (1 Monogenea, 4 Digenea, 2 Cestoda, 4 Nematoda, 3 Protozoa, 1 Mollusca) were recovered. Gyrodactylus bairdi, Epistylis sp., Trichodina sp., and Elliptio sp. infected the gills, while Myxobolus sp. occurred in the area between the branchiostegal rays. Crepidostomum sp., Bothriocephalus sp., Proteocephalus sp., Raphidascaris acus, and Rhabdochona cotti infected the intestine. Diplostomum sp. was found in the eye orbit, gonads, kidney, liver, and mesenteries. Neascus sp. infected the integument and Posthodiplostomum sp. occurred in the mesenteries. Tetracotyle sp. was found in the gonads, kidney, liver, mesenteries, muscle, and on the surface of the urinary bladder.

Gyrodactylus bairdi, Crepidostomum sp., and R. cotti were the only helminths found that mature in sculpins (Hoffman, 1967). The other trematode species occurred as larvae called metacercariae. The mean number of Crepidostomum sp. decreased in sculpins for the upriver to the downriver sites. Gyrodactylus bairdi, Crepidostomum sp., Neascus sp., Posthodiplostomum sp., Bothriocephalus sp., Proteocephalus sp., R. acus and Trichodina sp. had low prevalences and/or low mean intensities. Epistylis sp. had the highest prevalence of the external parasites found on sculpins. There were no significant difference in the prevalence of Epistylis sp. or Myxobolus sp. between seasons.

The number of parasite species found and the number of helminth species whose individuals were counted increased from FCU (12/7) and FEX (12/7) to FCD (14/10). The helminth fauna of sculpins from each site, made up of those species whose individuals were counted, are primarily composed of Tetracotyle metacercariae, followed by Diplostomum metacercariae and then R. cotti, demonstrating that the helminth faunas are similar between sites. The

helminths that will be discussed further are: Diplostomum sp., Tetracotyle sp., and R. cotti.

Comparisons of the mean numbers (Tables 9.6, 9.7, 9.8) of the common helminth species of sculpins between sites for the total sampling period show no significant differences for Diplostomum sp. and R. cotti. Sculpins from FEX had the highest mean number of Diplostomum sp., followed by sculpins at FCU. Sculpins from FCU had significantly higher mean numbers of Tetracotyle sp. than sculpins from FCD. The mean numbers of Tetracotyle sp. and R. cotti decreased from the upriver to the downriver sites.

Greater infection levels of Tetracotyle sp. and R. cotti in sculpins from FCU in comparison to FEX and FCD likely result from the higher productivity with accompanying algal growth observed there and the differences in bottom substrate. These factors presumably increase the numbers of intermediate hosts for these parasites which in turn increase the infection levels in sculpins at FCU.

Another explanation for this transitional decrease in numbers of Tetracotyle sp. and R. cotti may be due to differences in the lengths of sculpins examined from each site. Sculpins from FCU were significantly larger than sculpins from FEX and FCD but it appears this was not responsible for the trends shown by Diplostomum sp. and Tetracotyle sp.

Correlation coefficients between the length of infected sculpins and the number of their common parasites are in Table 9.9. The number of R. cotti significantly increased as sculpins from FEX and FCD increased in length and can be explained by the fact that as sculpins become larger (older), they eat more mayfly larvae, which serve as intermediate hosts for R. cotti (Hoffman, 1967). The number of Tetracotyle sp. decreased at FEX and significantly increased at FCU and FCD as sculpins increased in length. The number of Diplostomum sp. significantly decreased at all sites as sculpins increased in length and may be explained by a change in the sculpins' behavior and/or habitat. Close or direct contact between sculpins and cercariae (infective stage of trematodes) is required for penetration of the fish by the cercariae. Thus fish must be present where infected snails are or swim into the infected areas since cercariae have a limited swimming ability. Based on our observations, as sculpins

become older, they move from the shallows to the deeper water. Slyczynska - Jurewuz (1959) utilized cages to show that fish have a greater tendency to become infected with Diplostomum as they move closer to shore.

The mean Brillouin's diversity indices and mean evenness values for sculpins infected with helminths are in Table 9.10. Mean helminth diversity was highest in sculpins from all sites in 1983 when compared to the other years except for 1986 at FEX and 1984 at FCD. Mean helminth diversity was highest in sculpins from FEX in all four years; overall mean helminth diversity was also highest in sculpins from FEX. Evenness values, generally, followed the patterns mentioned above.

The overall mean helminth diversities for both infected sculpins and dace are comparable to those mean diversities of the helminth faunas reported for other fish species (Kennedy et al. 1986). The evenness values of the helminth faunas of both infected dace and sculpins are generally higher than the diversity indices because many dace and sculpins were infected with only two helminth species.

Summary

The parasite faunas of longnose dace between sites were comparable taxonomically and in species numbers. This was also true for the parasite faunas of sculpins between sites. The parasite faunas of each fish species at each site were composed primarily of larval parasites that mature in fish eating birds and fish. Of the helminths found, only Rhabdochona canadensis mature in dace while Crepidostomum sp. and Rhabdochona cotti mature in sculpins. Epistylis sp. was the most common external parasite of dace and sculpins. Quantitatively, Posthodiplostomum m. minimum metacercariae and Tetracotyle metacercariae were the most common helminths of dace and sculpins, respectively. Significant differences in the prevalence and mean number of the parasite species were not found between sexes of either host species. In dace, the number of P. m. minimum, Neascus sp., and R. canadensis at all sites, and the number of R. cotti in sculpins at FEX and FCD significantly increased as host length increased. The number of Tetracotyle sp. in sculpins at FCU and FCD significantly increased as sculpins increased in length. The number of

Diplostomum sp. significantly decreased at all sites and the number of Tetracotyle sp. decreased at FEX as sculpins increased in length. Tetracotyle sp. and R. cotti in sculpins, and P. m. minimum and Neascus sp. in dace decreased in mean numbers and prevalences from the upriver to the downriver sites. The mean number of R. canadensis was highest in dace from FCU and the prevalence of this nematode species decreased from the upriver to the downriver sites. The high overall mean Brillouin's diversity indices of counted helminths for both infected dace and sculpins are comparable to those mean helminth diversities reported for other fish species. Seasonal trends in infection rates for the parasites were not observed or were not consistent between years. Because of this and the extreme variation in the parasite data, longnose dace and sculpin age cohort analyses for the three most common helminth species in both fish species are in the process of being analyzed to determine if infection trends exist.

Future Research

Longnose dace and mottled sculpins will be collected seasonally from FCU, FEX, and FCD in 1987. The prevalence and mean number of the parasites infecting these fish species will be calculated. Statistical analyses for separating prevalences and mean numbers of the parasites found will be performed to determine differences between fish sex, sites, seasons, and years. Correlation analyses will be performed to demonstrate trends between fish length and the number of the common parasite species. Longnose dace and sculpin age cohort analyses for the three most common helminth species in both fish species are in the process of being analyzed to determine if trends exist. Longnose dace and sculpin include representatives of the 1980, 1981, 1982, 1983, 1984, 1985, 1986 and 1981, 1982, 1983, 1984, 1985, 1986 year classes, respectively. The mean number of the most common helminth species will be graphed in relation to fish age class and in what season they were collected.

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Table 9.1. Parasite fauna of 277 longnose dace from FCU during May 1983 through October 1986.

Parasite	No. infected (%)	No. counted (% of comm.)	Mean number + 1SD
Trematoda			
<i>Gyrodactylus</i> sp.	4 (1)	--	--
<i>Neascus</i> sp.	242 (87)	1923 (14.3)	7.9 ± 10.5
<i>Posthodiplostomum</i> s. <i>minimum</i>	269 (97)	10920 (81.2)	40.6 ± 55.8
Cestoda			
<i>Ligula intestinalis</i>	7 (3)	7 (0.05)	1.0
<i>Proteocephalus</i> sp.	10 (4)	13 (0.1)	1.3 ± 0.7
Nematoda			
<i>Haplonema hamulatum</i>	20 (7)	34 (0.25)	1.7 ± 1.9
<i>Raphidascaris acus</i>	3 (1)	3 (0.02)	1.0
<i>Rhabdochona canadensis</i>	136 (49)	545 (4.0)	4.0 ± 6.1
Protozoa			
<i>Epistylis</i> sp.	77 (28)	--	--
<i>Myxobolus</i> sp.	11 (4)	--	--
<i>Trichodina</i> sp.	48 (17)	--	--

Table 9.2. Parasite fauna of 417 longnose dace from FEX during May 1983 through October 1986.

Parasite	No. infected (n)	No. counted (# of com.)	Mean number ± 1 SD
Trematoda			
<i>Gyrodactylus</i> sp.	14 (3)	--	--
<i>Neascus</i> sp.	310 (74)	1932 (13.5)	6.2 ± 8.4
<i>Posthodiplostomus</i> s. <i>minimum</i>	372 (89)	11915 (83.3)	32.0 ± 41.1
Cestoda			
<i>Ligula intestinalis</i>	29 (7)	41 (0.3)	1.4 ± 1.1
<i>Proteocephalus</i> sp.	10 (2)	21 (0.1)	2.1 ± 2.3
Nematoda			
<i>Maplonema haemulatus</i>	48 (12)	110 (0.7)	2.3 ± 2.2
<i>Raphidascaris acus</i>	2 (0.5)	3 (0.02)	1.5 ± 0.7
<i>Rhabdochona canadensis</i>	118 (28)	288 (2.0)	2.4 ± 2.5
Acanthocephala			
<i>Neoechinorhynchus</i> sp.	1 (0.2)	1 (0.01)	1.0
Protozoa			
<i>Epiplatys</i> sp.	146 (35)	--	--
<i>Myxobolus</i> sp.	29 (7)	--	--
<i>Trichodina</i> sp.	73 (18)	--	--

Table 9.3. Parasite fauna of 421 longnose dace from PCD during May 1983 through October 1986.

Parasite	No. infected (N)	No. counted (n of sample)	Mean number ± SD
Trematoda			
<i>Gyrodactylus</i> sp.	13 (3)	--	--
<i>Haasius</i> sp.	269 (64)	1071 (15.9)	3.9 ± 4.2
<i>Posthodiplostomum</i> s. <i>minimum</i>	336 (80)	5290 (78.6)	15.7 ± 31.3
Cestoda			
<i>Ligula intestinalis</i>	19 (5)	22 (0.3)	1.2 ± 0.4
<i>Proteocephalus</i> sp.	25 (6)	58 (0.9)	2.3 ± 3.2
Nematoda			
<i>Haplonema hamulatus</i>	32 (8)	103 (1.5)	3.2 ± 3.6
<i>Raphidascaris acua</i>	1 (0.2)	2 (0.03)	2.0
<i>Rhabdochona canadensis</i>	59 (14)	182 (2.7)	3.1 ± 3.4
Protozoa			
<i>Epistylis</i> sp.	216 (51)	--	--
<i>Myxobolus</i> sp.	11 (3)	--	--
<i>Trichodina</i> sp.	92 (22)	--	--

Table 9.4. Correlation coefficients between length of infected longnose dace and number of *Posthodiplostomus minimum*, *Neascus* sp., and *Rhabdochona canadensis* by site.

Site	<i>Posthodiplostomus</i> s. <i>minimum</i>	<i>Neascus</i> sp.	<i>Rhabdochona canadensis</i>
FCU	0.75, 269**	0.38, 242*	0.39, 136*
FEX	0.62, 372*	0.36, 310*	0.26, 118*
FCD	0.43, 336*	0.17, 269*	0.70, 59*

* Correlation coefficient, number of infected fish.

** Significant at the 0.05 level or more.

Table 2.3 Mean bacterial diversity, richness and evenness values of the bacterial communities for infected bees between 2000 and 2006

Year	Index		
	SDI	PSI	PPI
2000	61.8 ± 13.7 (20) ¹	61.7 ± 13.3 (20)	22.0 ± 11.2 (20)
	0.14 ² ± 0.22 ³	0.227 ± 0.24	0.504 ± 0.31
	0.310 ± 0.21 ³	0.501 ± 0.30	0.261 ± 0.18
2004	71.1 ± 13.1 (20)	62.1 ± 11.3 (20)	23.0 ± 10.2 (20)
	0.226 ± 0.17	0.110 ± 0.11	0.302 ± 0.17
	0.572 ± 0.13	0.341 ± 0.16	0.500 ± 0.20
2005	60.0 ± 18.9 (19)	57.3 ± 13.6 (19)	20.7 ± 11.0 (19)
	0.092 ± 0.21	0.169 ± 0.21	0.300 ± 0.21
	0.510 ± 0.21	0.612 ± 0.22	0.528 ± 0.21
2006	76.2 ± 13.2 (20)	61.7 ± 11.1 (20)	23.2 ± 11.1 (20)
	0.527 ± 0.22	0.512 ± 0.21	0.612 ± 0.21
	0.510 ± 0.22	0.500 ± 0.21	0.701 ± 0.26
<hr/>			
Overall	58.8 ± 17.9 (20)	61.0 ± 11.1 (20)	20.0 ± 11.1 (20)
	0.432 ± 0.21	0.220 ± 0.20	0.267 ± 0.21
	0.450 ± 0.21	0.325 ± 0.26	0.577 ± 0.20

¹mean length (cm) of infected bees ± 1SD number of infected bees

²mean diversity ± 1SD

³mean evenness ± 1SD

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Table 9. / Parasite fauna of the collected molluscs from the Atlantic Bay, 1954 through October 1954

Parasite	No. infected	No. collected	No. available
Trematode			
<i>Cyrodactylus baili</i>	1 (1.0)	1	1
<i>Crepidostomus</i> sp.	6 (6.0)	65 (65.0)	55 (55.0)
<i>Diplostomus</i> sp.	170 (170.0)	555 (555.0)	555 (555.0)
<i>Tetracotyle</i> sp.	225 (225.0)	555 (555.0)	555 (555.0)
Nematode			
<i>Cyathostomoides tenuissimus</i>	1 (1.0)	1 (1.0)	1
<i>Maritrema hamulatus</i>	1 (1.0)	1 (1.0)	1
<i>Levinseni</i> sp.	1 (1.0)	1 (1.0)	1
<i>Abundochona</i> sp.	125 (125.0)	285 (285.0)	285 (285.0)
Protozoa			
<i>Epiplatys</i> sp.	255 (255.0)	255	255
<i>Myxobolus</i> sp.	65 (65.0)	65	65
<i>Trichodin</i> sp.	5 (5.0)	5	5
Mollusca			
<i>Elliptica</i> sp.	1 (1.0)	1	1

Table 3. Parasite fauna of sea bittles collected from PCB during May, 1960 through October 1960

	No. infected	No. counted	Mean number
Parasites	11	18 of 1000	1.8
Trematode			
<i>Gyrodactylus bairdi</i>	1 (1)	1	1
<i>Crepidulatus</i> sp.	6 (6)	12 (100)	2.0 ± 1.0
<i>Diogenes</i> sp.	112 (100)	675 (112)	6.0 ± 1.0
<i>Psithodulatus</i> sp.	1 (1)	1 (100)	1.0
<i>Tricostyle</i> sp.	222 (100)	420 (100)	1.9 ± 1.0
Cestode			
<i>Anthracoceros</i> sp.	1 (1)	1 (100)	1.0
<i>Tricostyle</i> sp.	1 (1)	1 (100)	1.0 ± 1.0
Nematode			
<i>Cyathodius tenuis</i>	1 (1)	6 (100)	6.0
<i>Marioneta hamulus</i>	6 (6)	6 (100)	1.0 ± 1.0
<i>Parasitulus acis</i>	1 (1)	1 (100)	1.0
<i>Phascolionella</i> sp.	40 (100)	50 (100)	1.2 ± 1.0
Protozoa			
<i>Enistylis</i> sp.	259 (75)	--	--
<i>Eyzobius</i> sp.	61 (10)	--	--
<i>Trichodina</i> sp.	7 (2)	--	--

Table 9.9. Correlation coefficients between length of infected mottled sculpins and number of Diplostomum sp., Tetracotyle sp., and Rhabdochona cotti by site.

Site	<u>Diplostomum</u> sp.	<u>Tetracotyle</u> sp.	<u>Rhabdochona cotti</u>
FCU	-0.24, 116 [†] *	0.26, 239*	0.11, 59
FEX	-0.17, 175*	-0.03, 336	0.32, 125*
FCD	-0.23, 132*	0.12, 323*	0.36, 40*

† Correlation coefficient, number of infected fish.

* Significant at the 0.05 level or more.

Table 9.10. Mean Brillouin's diversity indices and mean evenness values of the helminth communities for infected sculpins between sites and years.

Year	Sites		
	FCU	FEX	FCD
1983	59.7 ± 12.2 (87) ¹	50.7 ± 13.8 (106)	50.6 ± 13.3 (109)
	0.251 ± 0.22 ²	0.299 ± 0.24	0.199 ± 0.22
	0.315 ± 0.27 ³	0.364 ± 0.27	0.268 ± 0.29
1984	60.4 ± 17.6 (19)	48.9 ± 18.4 (100)	48.9 ± 18.9 (83)
	0.163 ± 0.20	0.262 ± 0.30	0.202 ± 0.21
	0.192 ± 0.21	0.281 ± 0.29	0.264 ± 0.70
1985	49.2 ± 15.3 (59)	47.2 ± 14.5 (56)	56.1 ± 18.9 (66)
	0.191 ± 0.22	0.208 ± 0.23	0.096 ± 0.16
	0.271 ± 0.30	0.265 ± 0.27	0.133 ± 0.22
1986	53.4 ± 21.1 (78)	47.9 ± 16.9 (79)	44.7 ± 15.1 (77)
	0.193 ± 0.22	0.327 ± 0.24	0.193 ± 0.23
	0.255 ± 0.30	0.407 ± 0.30	0.274 ± 0.32

Overall	55.2 ± 17.1 (243)	48.9 ± 16.1 (341)	49.9 ± 16.7 (335)
	0.212 ± 0.22	0.280 ± 0.26	0.178 ± 0.21
	0.275 ± 0.28	0.353 ± 0.29	0.242 ± 0.29

¹mean length (mm) of infected sculpins ± 1SD (number of infected fish)

²mean diversity ± 1SD

³mean evenness ± 1SD

UNIVERSITY OF WISCONSIN - MILWAUKEE
P. O. BOX 340
MILWAUKEE, WISCONSIN
53201

SUBCONTRACT NUMBER: E 06549-84-C-006

ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM:
WETLAND STUDIES

ANNUAL REPORT 1986

ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM:

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PROJECT COORDINATOR:

FOREST STEARNS
PROFESSOR

PREPARED BY: FOREST STEARNS (P.I.)
GLENN GUNTENSPERGEN (CO-P.I.)
JANET KEOUGH
DOUG WIKUM

RELEASING AUTHORITY:

RONALD D. HEDLUND
ASSOCIATE DEAN
GRADUATE SCHOOL
414-963-5920

UNIVERSITY OF WISCONSIN--MILWAUKEE
MILWAUKEE, WISCONSIN

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ABSTRACT

This report summarizes continuing studies that examine potential ELF generated electromagnetic field effects on peatland ecosystems in northern Wisconsin. Statistical analyses of decomposition data for 1986 demonstrated no significant differences among treatments although significant differences among bogs were evident. There were similar results for 1985 foliar nutrient content of three leaved false Solomon's Seal. In addition, there were significant plot within bog effects. Analysis of stomatal resistance for Labrador Tea during July indicated a significant difference among ELF categories, however, this difference was not evident in August. In both months, there were significant differences among bogs (subgroups).

SUMMARY

This report summarizes the results of field studies and laboratory analyses for 1985 and 1986. In these studies we have been investigating the possible effects of ELF electromagnetic fields on 11 bogs in the vicinity of the Wisconsin Test Facility. Our studies focused on foliar nutrient concentration, rate of decomposition, and stomatal resistance all variables that could be influenced by ELF electromagnetic fields.

All bogs were sampled approximately monthly during the growing season. Foliar samples were collected in June, July, August and September in 1985 and 1986. Analysis of 1985 data from three leaved False Solomons Seal, leatherleaf, and Labrador Tea indicate seasonal changes in nutrient concentration. Nested analysis of variance models were used in an attempt to distinguish the categories of bogs along the ELF field gradient. Although no differences were found among categories (treatments) statistically significant differences were found among the subgroups (bogs) and subsubgroups (plots) in every analysis.

Stomatal resistance measurements were made in July and August 1986. Labrador Tea was chosen for study because of its relatively large leaf size. Significant treatment effects were detected in July but not in August.

Decomposition samples were collected in June 1986, after having been in place for one year. We used Labrador Tea leaves; a natural bog material. In general, variation in weight loss of Labrador Tea leaves was comparable to variation in stomatal resistance and nutrient concentration. No treatment effects were

detected with our ANOVA models but significant differences among subgroups (bogs) were found.

INTRODUCTION

The objective of this research is to determine whether long-term exposure to ELF electromagnetic fields can significantly influence the stability and functioning of peatland ecosystems. A series of experiments with plants exposed to high intensity 60Hz fields ($>200\text{v/M}$) suggest that if ELF fields were to have any effect, then the site of action of the applied fields would be the cell membrane (Inoue et al. 1985, Miller et al. 1980, 1983). Therefore, we chose a set of variables important to peatland ecosystem structure and function that could potentially be affected at the cell membrane level. The three variables that were investigated were: decomposition rate, foliar nutrient concentration, and stomatal resistance. Alterations in these processes could have important effects at the ecosystem level.

Eleven peatland sites located along the electromagnetic field gradient produced by the Wisconsin Test Facility were chosen for study (Figure 1). These eleven sites have similar species composition, structure, and environmental characteristics. All sites have an organic peat (histosol) substrate formed by the partial decomposition of mosses and vascular plants.

In 1985 and 1986, each site was visited monthly (May-October) and samples collected according to our experimental design and sampling protocol. Foliar samples and decomposition bags were collected in 1985 and 1986. Labrador Tea leaf transpiration measurements were made twice in 1986. A fourth work element, nitrogen fixation rate was dropped because of a large

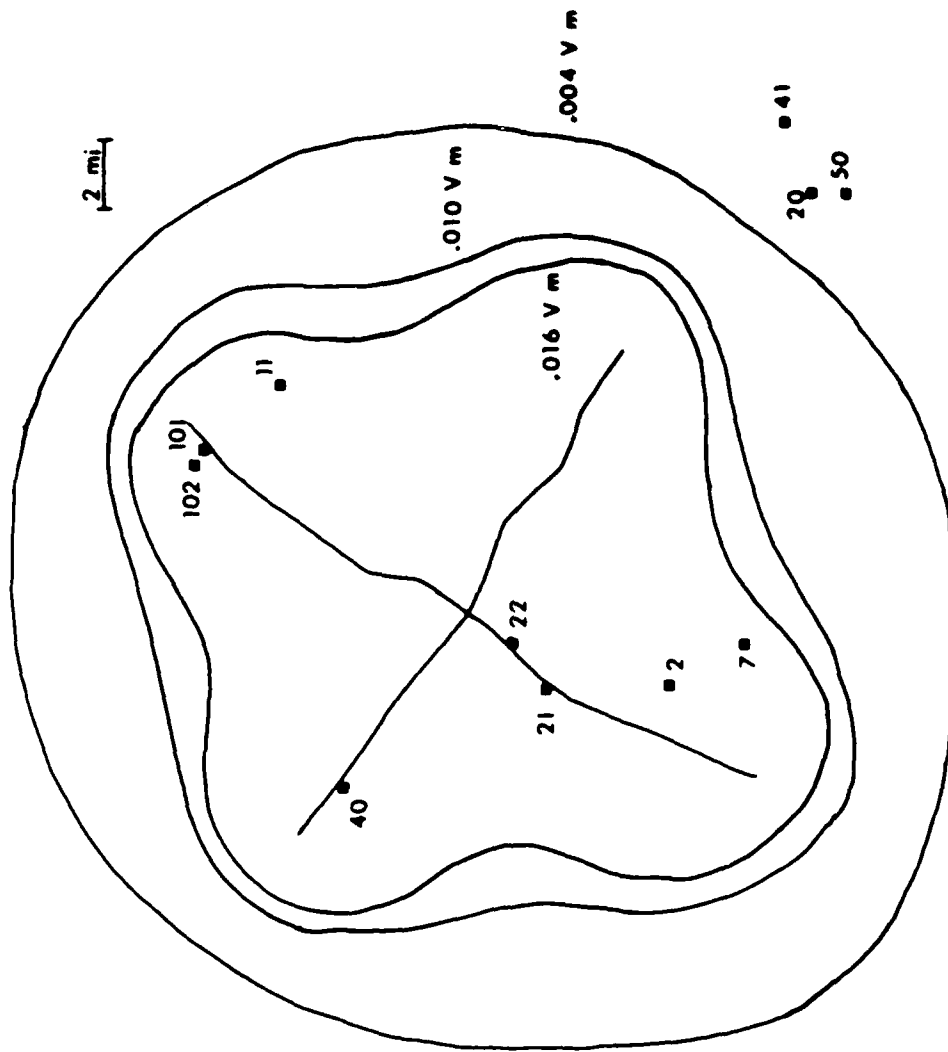


Figure 1. Map showing the location of bog study sites (GROUND = 101, 102; ANTENNA = 21, 22, 40; INTERMEDIATE = 2, 7, 11; and BACKGROUND = 20, 41, 50) along the ELF 76 Hz electromagnetic gradient produced by the Wisconsin Test Facility.

degree of variability, between sites and the rates of litter or fixation. To obtain accurate measurements would have necessitated longer sampling periods than were feasible.

The operational capability of the WFF has changed since 1983. In 1984 the WFF was upgraded but was not fully operational until the last quarter of 1984. For the first three quarters of 1985 the antenna operated intermittently and at low altitudes. It was not until 1986 that the WFF was fully operational. All field exposures have changed over the course of our study and will be taken into account in future analyses.

Experimental design

This study was designed to evaluate direct ionospheric and analysis of variance techniques to identify any significant effects of ELF electromagnetic fields on measures of ecosystem function. ELF fields were measurable at all test sites, including those designated as background. In addition, the White Sands Test Facility has been operating for several years. Because of these facts, we felt we could not use a design that involved test vs. control paired plots. Instead we designed a student's t analysis approach, with sites at selected points to allow for both ELF gradient effects (Table 1).

Four categories of sites were selected, based on ELF intensity. The ANTENNA group includes wetlands adjacent to the antenna system, the INTERMEDIATE group are sites located between the antenna area, the BACKGROUND group are sites that have field 76 Hz intensities at least two orders of magnitude lower than the antenna sites, and the GP-UM sites are adjacent to the north ground terminal. We monitored three lots in each of the ANTENNA, INTERMEDIATE, and BACKGROUND categories, and two GP-UM transects within one large bog (Table 1). The bogs are similar in vegetation composition and structure and in groundwater chemical constituents (see Stearns et al. 1984). In 1984 we shifted the position of our original sampling area in Bog 21 because of a concern over the high density of spruce trees. The new sampling area had lower spruce density than the original and also met our other criteria for species composition and water quality.

Within each site, a transect was established parallel to the

Table 1. A list of dogs in the Clear Lake area investigated during 1985 and 1986.

Dog Name	EHE Category
101	GRUUM
102	GRUUM
21	ANTENNA
22	ANTENNA
40	ANTENNA
2	INTERMEDIATE
7	INTERMEDIATE
11	INTERMEDIATE
20	BACKGROUND
41	BACKGROUND
50	BACKGROUND

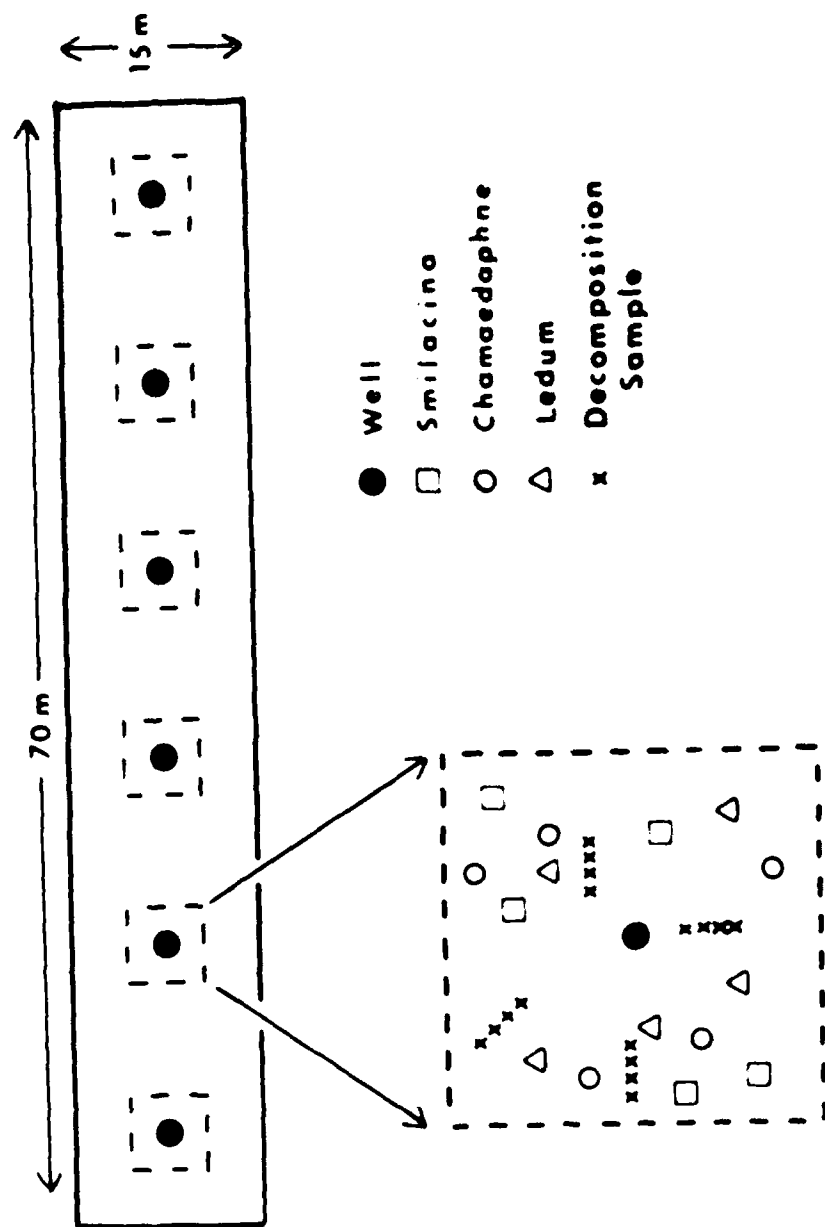


Figure 2. The 70 x 15 meter sample plot design used in 1986 for each of the eleven study sites. Each plot was subdivided into six subplots. Foliar samples for nutrient analysis and the decomposition samples, as well as appropriate environmental data, were collected within each subplot.

nearest antenna arm or ground terminal. Six shallow groundwater wells were placed 10 m apart, and the environmental and experimental samples were collected from and adjacent to these well sites (Figure 2).

ANALYSES

All analyses were performed on a Sperry 1100 computer using procedures available in SPSS (Hull and Nie 1981) and programs available in the BIOM statistical package (Rohlf). Sokal and Rohlf (1981) served as the principal statistical reference. The data sets were examined for normality using the moment statistics and the Kolmogorov-Smirnov test statistic. The Scheffe' - Box log-anova test was used to test for homogeneity of variances. In some cases, appropriate transformations were made before further statistical testing. For instance, since most of our test data are percentages (between 0 and 1.0), we used a square-root arcsin transformation to normalize the data.

A nested analysis of variance model (shown below) was used to test for significant effect of ELF level category and subgroups (Bogs) on the measured variables.

$$Y_{ijkl} = u + a_i + B_{ij} + C_{ijk} + e_{ijkl}, \text{ where:}$$

Y = sample value for the dependent variable

u = grand mean

a_i = ELF treatment (ANTENNA, INTERMEDIATE, BACKGROUND, GROUND)

B_{ij} = replicate bog nested within ELF treatment

C_{ijk} = replicate plots nested within bogs

e_{ijkl} = error term

To test for differences among groups (ELF treatments), we divided group mean squares by subgroup (replicate bogs) mean squares to produce the appropriate F statistic. Differences among subgroups (bogs) were tested by dividing subgroup mean squares by plot mean squares and differences among plots by dividing plot mean squares by the within plots (error) mean squares to produce the appropriate F statistic.

Although we chose bogs that were structurally and chemically similar, there was some variation in bog species composition, overstory tree density, and environmental chemistry. The nested design was used to separate variation inherent among the replicate bogs from variation assignable to ELF category. Even if there were significant bog differences we can still test to see if the variation among the ELF treatments is greater than that expected on the basis of the variation among the replicate bogs.

When significant group (treatment) or subgroup (bog) differences were determined in the nested ANOVA analysis, we conducted "unplanned multiple comparisons of means tests". Potentially significant differences among all combinations of pairs of means were tested using the GT2 method described in Sokal and Rohlf (1981).

ENVIRONMENTAL PARAMETERS

A variety of water quality parameters were measured in each transect in each bog to assist in explaining test results. In 1985 and 1986, water samples were collected and measurements made at the six sample wells located in each transect at monthly intervals from May through September. ELF field intensities were measured once each year in each bog by IITRI personnel. A summary of the water quality parameters is presented in APPENDIX A.

We routinely measured pH, specific conductance, depth from peat surface to ground water, and water temperature. Water samples were collected, filtered, and divided into two aliquots. One aliquot was refrigerated and later measured for color. Color was measured by absorbance at 320 nm on a spectrophotometer. The duplicate aliquot was acidified with nitric acid and later analyzed for cation concentration with an atomic absorption spectrophotometer.

The 1986 data for water temperature, pH, and specific conductivity are presented in Figures 3-5. Water temperature (Figure 3) shows a steady increase in each bog until July then decreases through August and September. This reflects the seasonal trend in air temperature. pH and specific conductivity are indicators of potential differences in the composition and function of peatlands. There are no overall trends in pH of the the interstitial bog waters and pH remains relatively constant throughout the year in each bog (Figure 4). However, specific conductivity varies throughout the year and between bogs (Figure

5). Both pH and specific conductivity values are within the range typical for ericaceous-sedge bogs with a spruce-tamarack canopy.

WATER TEMPERATURE

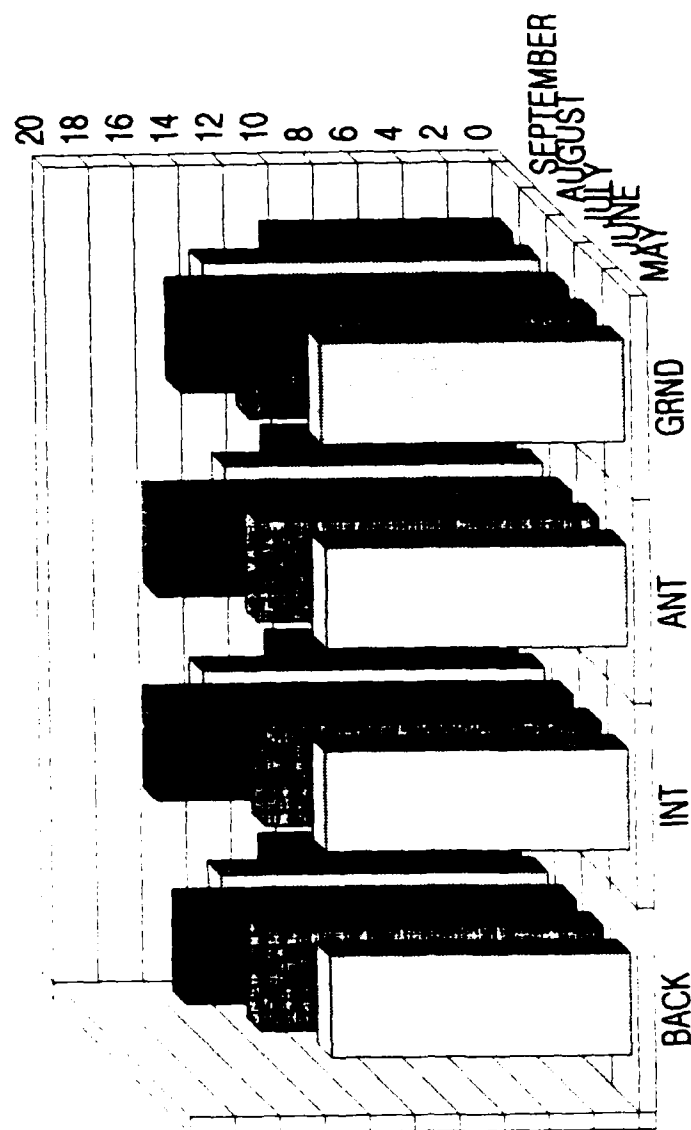


Figure 3. Mean temperature ($^{\circ}$ C.) of groundwater found in the bog treatment groups during 1986.

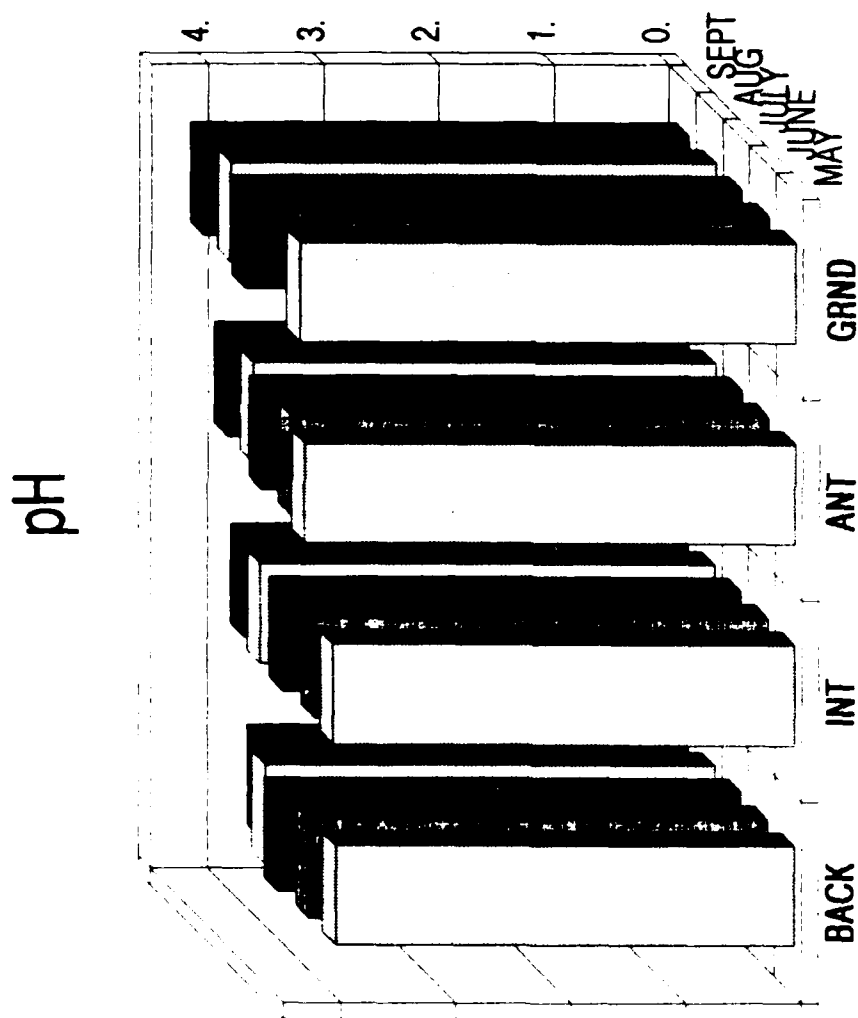


Figure 4. Mean pH of groundwater found in the bog treatment groups during 1986.

CONDUCTIVITY 1986



Figure 5. Mean conductivity (uS / cm) of groundwater found in the bog treatment groups during 1986.

STOMATAL RESISTANCE

Leaf stomata are regulated by many environmental and internal factors. As ELF fields are hypothesized to operate at the membrane level, it is possible that they may affect the regulation of stomatal opening or closing.

The status of the stomata can significantly affect photosynthesis and plant growth. For instance, water stress is well correlated with stomatal closure and reduced photosynthesis. The mineral element status of a plant may also affect stomatal opening. Hsiao (1975) reviewed a number of studies correlating plant nutrient status with stomatal behavior. He pointed out that even mild potassium deficiency can restrict stomatal opening. Evidently, the mechanistic explanation involves the importance of potassium in affecting the turgor of guard cells that underlies stomatal control.

Labrador Tea leaves were measured while attached to the twig in accordance with suggestions by the LI-COR manufacturer, suggestions from personnel at the Duke University Phytotron facility, and following a protocol we developed in 1985. Only expanded new leaves were used. Old leaves had begun to senesce by mid-summer and might have given spurious readings. We measured only when sunlight levels were above 400 microeinsteins $m^{-2} sec^{-1}$ (PAR).

We completed two sets of measurements, - one in July and the other in late August (Tables 2-3 and Figs. 6-7). Each sampling period spanned several days during which light levels varied but never dropped below our minimum acceptance level. Thirty readings

Table 2. Summary of July 1986 Labrador Tea stomatal resistance measurements (s/cm).

BOG	TYPE	MEAN	S.E.	N	C.V.
2	1	1.86	.05	30	16
7	1	2.12	.05	30	12
11	1	2.07	.07	30	19
21	2	1.29	.04	30	11
22	2	1.83	.03	30	09
40	2	1.49	.03	30	18
20	3	2.02	.05	30	11
41	3	2.18	.07	30	16
50	3	2.06	.07	30	18
101	4	1.85	.04	30	10
102	4	2.06	.05	30	14

TYPE: 1=Ground site, 2=Antenna site, 3=Intermediate site, 4=Background site

C.V. (coefficient of variation) = (standard deviation/mean)100

STOMATAL RESISTANCE

JULY 1986

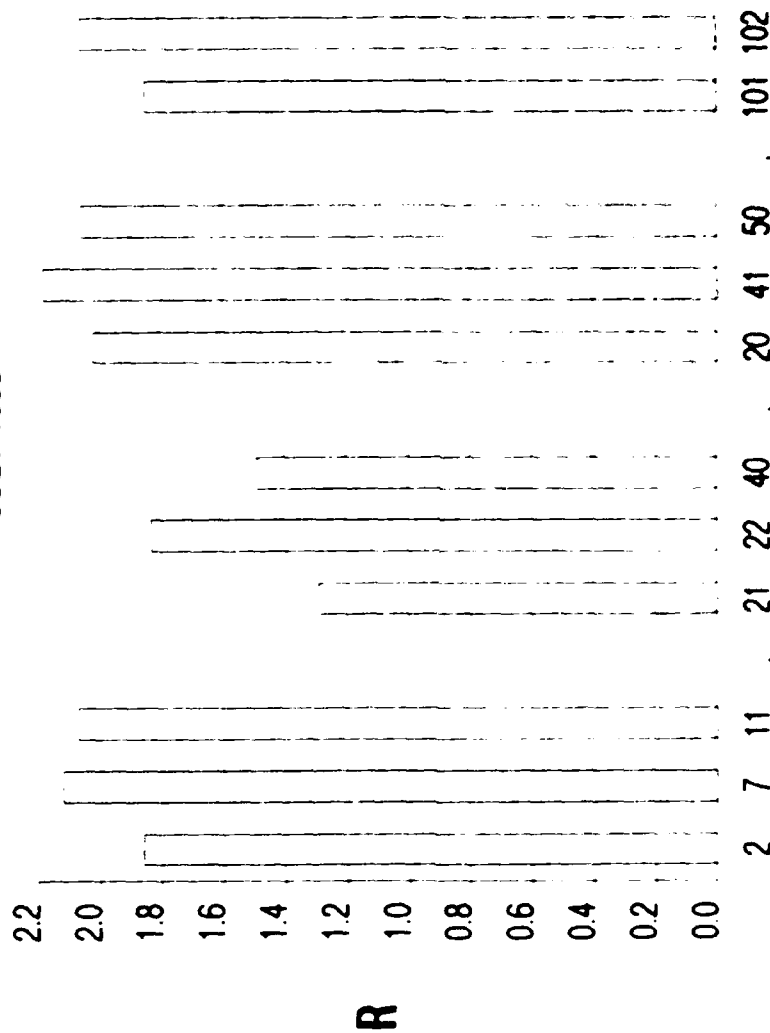


Figure 6. Mean stomatal diffusion resistance (R, sec cm) by Liodum groenlandicum in July, 1986.

Table 3. Summary of August 1986 Labrador Sea stenatal resistance (s/cm) measurements.

BOG	TYPE	MEAN	S.E.	N	C.V.
2	1	2.07	.06	30	17
7	1	2.28	.07	30	17
11	1	2.02	.05	30	14
21	2	1.78	.08	30	14
22	2	2.40	.06	30	14
40	2	1.85	.07	30	20
20	3	2.10	.05	30	14
41	3	1.98	.04	30	12
50	3	1.84	.06	30	17
101	4	1.97	.06	30	16
102	4	1.91	.06	30	18

TYPE: 1=Ground Site, 2=Antenna Site, 3=Intermediate Site, 4=Background Site

C.V. (Coefficient of Variation) = (standard deviation/mean)100

STOMATAL RESISTANCE

AUGUST 1986

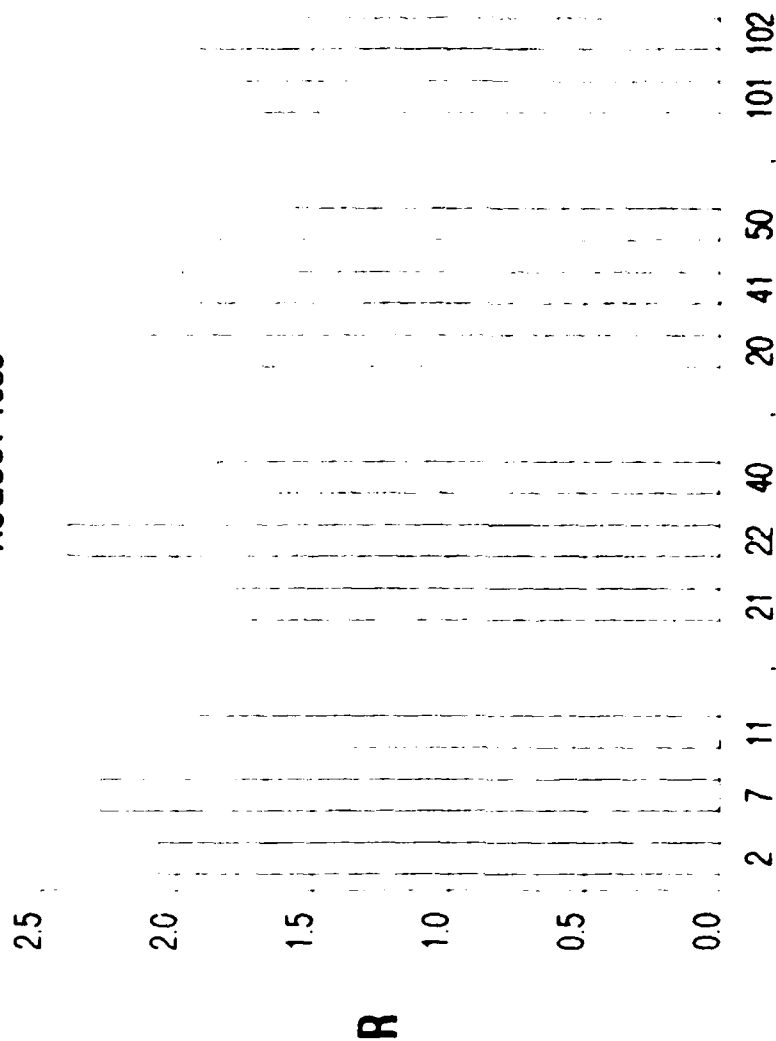


Figure 7. Mean stomatal diffusion resistance (R, sec/cm) by *groenlandicum* in August, 1986.

were taken in each of the eleven bogs for each of the two measurement periods.

We examined both data sets using a nested analysis of variance model (Table 4). This analysis detected significant ($P < 0.05$) treatment effects, significant bog effects, and significant plot effects for the July data. The use of an "unplanned multiple comparisons test of means" (GT2 method, used because sample sizes are very unequal) indicated that the ANTENNAE treatment differed from the BACKGROUND treatment but not from either the GROUND or INTERMEDIATE treatments. We have not yet received the 1986 ELF measurements taken for us by IITRI so we used 1985 measurements for the earth and magnetic fields to examine the correlation between ELF fields and stomatal resistance. Significant correlations were found for both comparisons (Table 5). Air fields were not measured in every plot in 1985 and so we could not determine the correlation coefficients for air fields and stomatal resistance. Air fields were measured in 1986 and that correlation will be determined when the data are available.

We also examined the percentage of variation attributable to the sublevels: 24.7% among bogs, 16.5% among plots within bogs, and 58.8% among stomatal resistance measurements within plots (Table 4). In view of the high percentage of variation among replicate readings, we will further examine and refine our measurement techniques.

Each time we measured stomatal resistance we also measured other parameters including: light level, air temperature, leaf temperature, cuvette temperature, and relative humidity. We plan

Table 4. Results of 3 level nested analysis of variance for stomatal resistance of Labrador Tea in 1986.

<u>Source of variation</u>	<u>SS</u>	<u>df</u>	<u>F</u>	<u>Sign.</u>
JULY 1986				
Treatment	16.7	3	5.84	.025
Bog	6.7	7	12.09	.001
Plot	8.4	55	2.40	.001
Error	16.8	264		

AUGUST 1986

Treatment	0.53	3	1.60	NS
Bog	0.77	7	7.64	.001
Plot	1.60	55	2.57	.001
Error	2.99	264		

Percentage of total variance components

	July	August
Bog	24.7	15.3
Plot	16.5	20.2
Error	58.8	64.5

Table 5. Pearson correlation coefficients (r) for July porometer readings (R=s/cm) and light intensity and ELF fields (N=66).

	R	
Light intensity	.04	(p=.372)
Earth ELF field	-.43	(p=.000)
Magnetic ELF field	-.68	(p=.000)

to test the suitability of using one or more of these parameters in an analysis of covariance. Presumably light level has an influence on stomatal status; however, the low pearson correlation coefficient (r) between light and July stomatal resistance readings was not significant (Table 5).

In contrast to the July data, no significant treatment effects were found in a nested analysis of variance of the August data. Significant subgroup (bog) effects were detected. We again examined the percentage of variation attributable to the sublevels: 15.3% among bogs, 20.2% among plots within bogs, and 64.5% among stomatal resistance measurements within plots. As in the July sample, a high percentage of the variation is among replicate readings.

The results of the July and August measurements are inconsistent. We will spend more effort on this phase of our study next year in an effort to confirm our initial July findings. We intend to examine our sampling technique more closely, increase our sample size to increase the power of our analysis, and make use of covariates in our analysis.

DECOMPOSITION

Labrador Tea leaves were collected from Bog 41 (a BACKGROUND site) in September 1984. Labrador Tea usually has 3 to 4 cohorts of leaves present on the plant during the summer. We collected senescent leaves that were still attached to the plant stems; these leaves, representing the oldest cohorts, would have fallen off naturally within one or two weeks of our collection.

Subsamples of leaves were air dried, weighed (approximately 0.5 grams), and placed in 2mm mesh fiberglass bags with a numbered tag. The bags were randomly distributed into 264 groups of 4 bags each tied together with a long piece of nylon line. In June 1985, 4 groups of 4 bags were placed in hollows in each of the 6 subplots in each bog (24 groups in each bog, refer to Figure 2). The bags were placed flat on the bog surface and the line for each group tethered to a fiberglass rod to facilitate retrieval. Positioning samples on the bog surface simulates the more natural placement of leaves that fall from the plants and begin to decompose on the peat surface. Sphagnum moss in the hollows grew over our sample bags during the summer so we believe that conditions for decomposition were reasonably natural and homogenous. We removed two bags from each group of four in June 1986 after twelve months of incubation. The leaves were removed from the bags, dried, and reweighed to obtain percentage weight loss.

Average weight loss within each bog is presented in Table 6 and Figure 8. The coefficients of variation are relatively low (less than 35%) for these samples resembling the low values we

Table 6. Mean percentage weight loss for Labrador Tea leaves placed on the peat substrate following 12 months incubation (June 1985 to June 1986).

BOG	TYPE	MEAN	S.E.	N	C.V.
2	1	21.94	0.53	48	17
7	1	27.54	1.28	48	32
11	1	21.09	0.92	48	30
21	2	23.26	1.45	48	39
22	2	20.52	0.83	48	25
40	2	20.87	0.78	48	26
20	3	25.45	0.56	48	19
41	3	25.42	1.21	48	33
50	3	22.74	1.22	48	33
101	4	26.15	0.93	48	28
102	4	23.67	1.21	48	32

DECOMPOSITION **ONE YEAR WEIGHT LOSS**

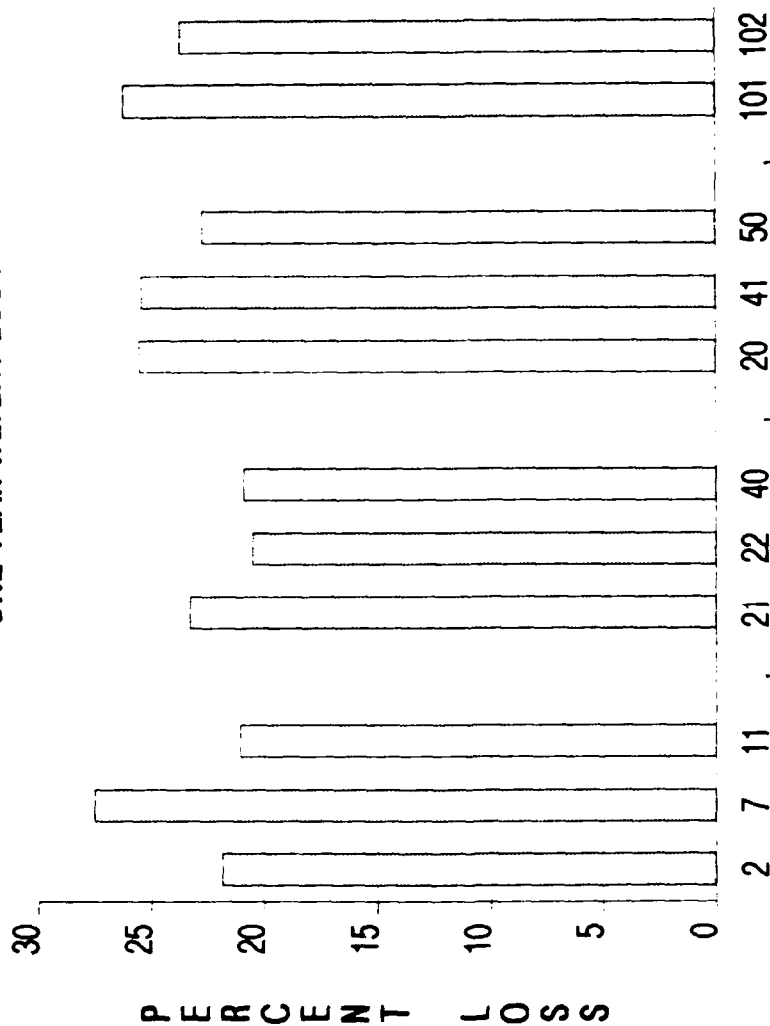


Figure 8. Mean weight loss by samples of Ledum groenlandicum after one year incubation (June, 1985 - June, 1986) on the surface of each bog.

found for mineral nutrients in past years. Nested analysis of variance showed no significant ELF treatment effects for this decomposition sample set (Table 7). However, there was a significant subgroup (Bog) effect. Thus, there is some heterogeneity among bogs for this variable. We have also calculated the percentage variation attributable to the nested levels: 7.5% for bogs, 2.8% for plots within bogs, and 89.7% for bags within plots. The plots represent the decomposition rates of the bogs but there is a considerable degree of variation associated with either the placement of bags in the hollows or the representativeness of the material placed in each bag.

We collected Labrador Tea leaves all from one small area and thoroughly mixed them before they were placed in the bags. However, when the litter bags were collected we noticed that mosses had not grown evenly over them. Therefore, as bags were collected, we quantified the amount of moss cover using a ranking system ranging from completely covered (4) to no moss cover lying exposed on the surface (1). We will use this additional data in analyses to account for more of the variation present in this design.

In the fall of 1986, we again collected Labrador Tea leaves and prepared and placed litter bags in November. Ninety-six sample bags were randomly placed in hollows in each bog following our earlier design. We took care to position these bags to ensure natural moss growth over each. These samples will remain in place for one year before collecting in 1987.

Table 7. Results of a three nested analysis of variance for decomposition of Labrador Tea leaves from June 1985 to June 1986.

<u>Source of variation</u>	<u>SS</u>	<u>df</u>	<u>F</u>	<u>Sign.</u>
Treatment	.00086	3	1.37	NS
Bog	.00063	7	4.19	.001
Plot	.00015	55	1.25	NS
Error	.00012	462		

Percentage of total variance components

Bog	7.5
Plot	2.3
Error	90.2

LEAF CATIONS

The three cations: calcium, potassium, and magnesium, represent important constituents of plant tissue whose uptake and concentration in a plant may be affected by ELF fields. These mineral nutrients play important roles in plant physiology and are active constituents of a number of important biochemical reactions.

We collected foliar samples several times during the growing season because the translocation of nutrients may vary seasonally and the pattern of nutrient accumulation may be affected. Thirty-six foliar samples were collected from 36 individuals of each species in each bog. Chamaedaphne calyculata (Leatherleaf) was collected in June, August, and September. Smilacina trifolia (three-leaved false Solomon's Seal) was collected in June, July, and August. In 1985, we collected Ledum groenlandicum (Labrador Tea) in only 4 bogs representing the four ELF treatments. We sampled these four sites to determine the variation associated with the nutrient concentration of that species. We had stopped using the two sedges sampled in 1983 and 1984 because they were not abundant and would not be sufficient for a sampling program lasting through 1987. Labrador Tea is abundant in all our sites and seemed a reasonable substitute. Picea mariana (black spruce) samples were collected only in September. We followed the recommendations of Swan (1970), who suggested that fall samples are the best to evaluate the nutrient status of black spruce.

All foliar samples were prepared for analysis by digestion

in a mixture of sulfuric acid and hydrogen peroxide that oxidizes the organic material in the sample (van Lietrop 1976). National Bureau of Standards pine needle and citrus leaf standards were processed using this procedure and analyzed with satisfactory results. Complete sample sets for spruce, leatherleaf, Labrador Tea, and three-leaved false Solomon's Seal have been analyzed for all three nutrient elements.

Mean concentrations (percent of dry weight) of potassium, calcium, and magnesium for the three collections of three-leaved false Solomon's Seal appear in Tables 8 through 10. The seasonal trends for each element are similar for each of the four ELF treatments (Figures 9-11): calcium and magnesium concentration increases over the course of the year while potassium concentration declines from June to August. Nutrient concentrations are noticeably different in August than June for calcium and magnesium while potassium concentrations are much higher in June than August.

Seasonal trends for calcium and potassium were similar in leatherleaf and Labrador Tea as for three-leaved false Solomon's Seal (Tables 11-13). Magnesium concentrations for Labrador Tea were also similar to three-leaved false Solomon's Seal, but in leatherleaf magnesium concentrations were nearly constant between June and August. Despite these similarities in seasonal trends, each species had a different concentration of nutrients in their foliar tissue throughout the year (see also Table 14 for spruce data).

Table 8. Cation concentration (percent dry weight) in Smilacina trifolia foliar tissue collected in June 1985.

Potassium			
BOG	Mean	S.F.	C.V.
2	1.90	.053	16.7
7	2.96	.081	16.2
11	2.35	.063	16.1
21	3.21	.099	18.7
22	3.10	.125	24.2
40	3.17	.086	16.4
20	2.74	.065	14.2
41	3.22	.089	16.5
50	3.42	.073	12.9
101	2.58	.068	15.9
102	3.03	.084	16.5

Calcium			
2	.31	.009	18.6
7	.35	.011	19.3
11	.31	.011	22.2
21	.40	.016	23.3
22	.39	.012	18.2
40	.25	.006	14.1
20	.34	.011	18.6
41	.30	.011	21.1
50	.32	.014	25.2
101	.33	.016	28.7
102	.34	.009	16.1

Magnesium			
2	.15	.003	11.8
7	.13	.003	12.2
11	.14	.005	21.3
21	.17	.004	15.8
22	.15	.003	13.0
40	.19	.004	11.8
20	.16	.004	14.7
41	.13	.003	15.8
50	.20	.006	16.8
101	.14	.002	14.8
102	.13	.002	15.9

Table 9. Cation concentration (percent dry weight) in Smilacina trifolia foliar tissue collected in July 1985.

Potassium

BOG	Mean	S.E.	C.V.
2	2.08	.081	23.6
7	2.73	.057	12.5
11	2.19	.055	15.1
21	2.67	.102	22.8
22	2.32	.083	21.6
40	2.41	.072	17.8
20	2.66	.077	17.3
41	2.83	.088	18.7
50	3.65	.098	16.2
101	2.22	.050	13.5
102	2.65	.065	14.7

Calcium

2	.42	.012	16.7
7	.44	.008	11.4
11	.41	.013	19.5
21	.58	.025	25.9
22	.49	.015	17.8
40	.29	.009	18.3
20	.44	.017	23.2
41	.34	.013	22.4
50	.41	.014	21.0
101	.39	.016	23.8
102	.41	.009	12.9

Magnesium

2	.16	.004	17.8
7	.15	.003	12.7
11	.20	.006	17.9
21	.18	.006	19.0
22	.15	.006	24.5
40	.17	.005	18.2
20	.19	.006	19.3
41	.12	.004	17.7
50	.22	.008	22.3
101	.15	.005	18.6
102	.13	.003	15.2

Table 10. Cation concentration (percent dry weight) in Smilacina trifolia foliar tissue collected in August 1985.

BOG	MEAN	S.E.	C.V.
Potassium			
2	1.95	.095	29.2
7	2.52	.058	13.8
11	1.69	.060	21.3
21	2.30	.073	19.1
22	2.08	.068	19.7
40	2.28	.083	21.9
20	2.19	.070	19.2
41	3.11	.098	19.0
50	3.01	.070	14.0
101	1.91	.058	18.3
102	2.25	.072	19.1
Calcium			
2	.64	.017	16.1
7	.77	.024	18.7
11	.77	.021	16.4
21	.76	.026	20.1
22	.78	.018	13.8
40	.42	.013	18.8
20	.90	.022	14.3
41	.57	.025	26.5
50	.70	.029	24.4
101	.64	.022	21.1
102	.67	.011	13.3
Magnesium			
2	.21	.006	17.4
7	.18	.006	19.8
11	.28	.013	29.0
21	.22	.007	19.8
22	.20	.007	21.0
40	.20	.008	23.2
20	.28	.011	23.0
41	.17	.005	17.6
50	.28	.013	28.8
101	.22	.008	22.5
102	.15	.006	25.7

POTASSIUM (SMILICINA) PERCENT DRY WEIGHT

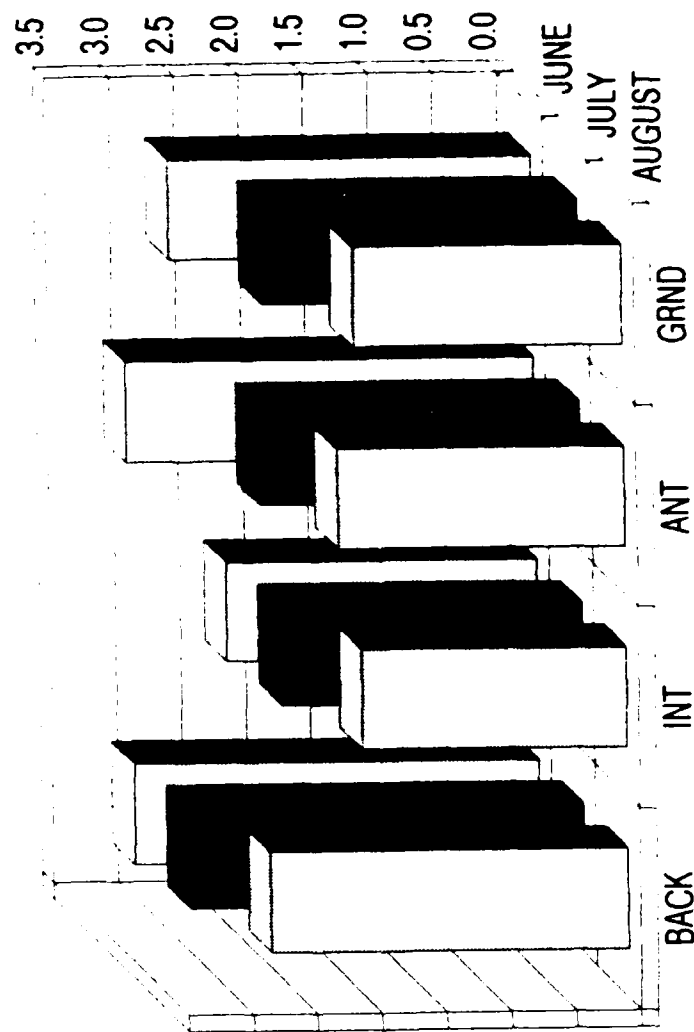


Figure 9. Mean potassium content of Smilacina leaves from each bog treatment group during 1985.

CALCIUM (SMILICINA) PERCENT DRY WEIGHT

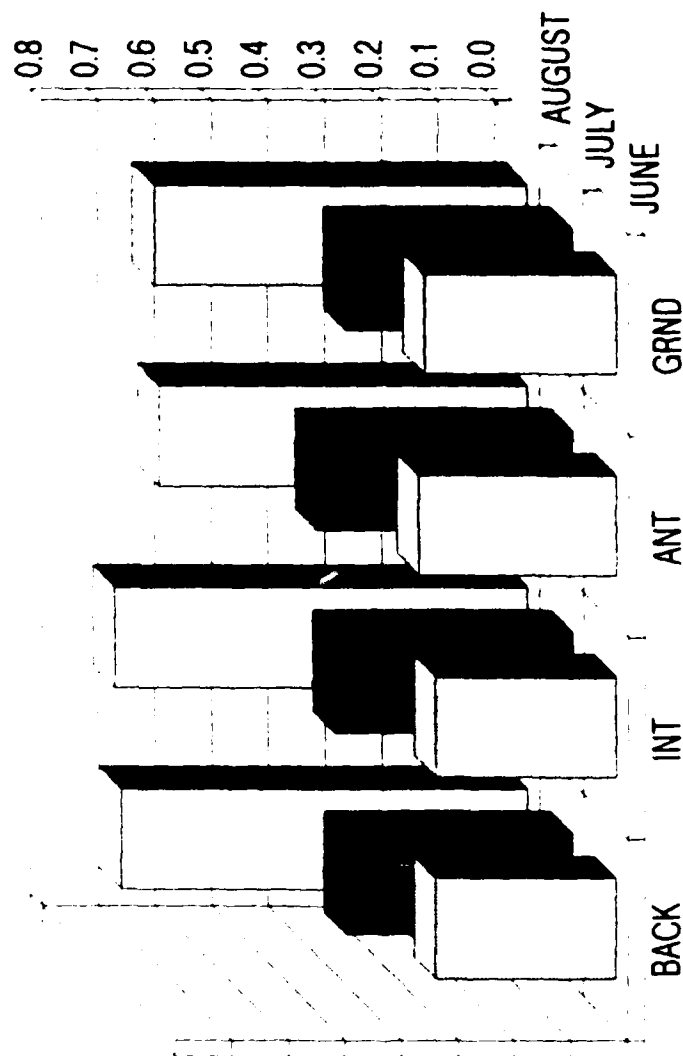


Figure 10. Mean calcium content of *Smilacina* leaves from each bog treatment group during 1985.

MAGNESIUM (SMILICINA) PERCENT DRY WEIGHT



Figure 11. Mean magnesium content of Smilacina leaves from each bog treatment group during 1985.

Table 11. Cation concentration (percent dry wieght) in leatherleaf foliar tissue collected in June 1985.

BOG	Mean	S.E.	C.V.
Potassium			
2	.57	.011	11.0
7	.66	.013	12.0
11	.67	.014	12.0
21	.66	.013	12.0
22	.70	.018	15.0
40	.57	.014	14.0
20	.77	.031	24.0
41	.69	.028	24.0
50	.79	.032	24.0
101	.56	.013	14.0
102	.60	.013	13.3
Calcium			
2	.45	.014	19.0
7	.36	.010	16.0
11	.39	.018	28.0
21	.42	.011	16.0
22	.39	.009	15.0
40	.37	.011	18.0
20	.41	.014	21.0
41	.40	.014	21.0
50	.42	.016	23.0
101	.46	.016	21.0
102	.35	.012	21.0
Magnesium			
2	.13	.003	12.0
7	.13	.002	11.0
11	.11	.002	12.0
21	.12	.002	9.0
22	.11	.002	12.0
40	.11	.002	12.0
20	.13	.004	17.0
41	.13	.003	13.0
50	.13	.002	11.0
101	.13	.003	16.0
102	.12	.003	14.0

Table 12. Cation concentration (percent dry weight) in leatherleaf foliar tissue collected in August 1985.

BOG	MEAN	S.E.	C.V.
Potassium			
2	.48	.008	10.0
7	.48	.013	16.0
11	.48	.008	10.0
21	.49	.008	10.0
22	.53	.011	13.0
40	.55	.010	10.0
20	.52	.010	12.0
41	.50	.007	8.0
50	.50	.011	14.0
101	.46	.010	13.0
102	.48	.013	16.0
Calcium			
2	.59	.013	13.0
7	.52	.019	18.0
11	.65	.019	18.0
21	.55	.014	15.0
22	.65	.023	21.0
40	.58	.016	17.0
20	.56	.017	18.0
41	.62	.026	25.0
50	.50	.014	17.0
101	.64	.023	21.0
102	.54	.022	24.0
Magnesium			
2	.12	.003	13.0
7	.12	.004	18.0
11	.10	.003	17.0
21	.12	.003	13.0
22	.13	.003	13.0
40	.11	.003	15.0
20	.12	.003	13.0
41	.12	.003	13.0
50	.12	.003	14.0
101	.14	.003	14.0
102	.13	.002	11.0

Table 13. Cation concentration (percent dry weight) for Labrador Tea foliar tissue collected in 1985.

		Potassium		Calcium		
JUNE						
BOG	Mean	S.E.	C.V.	Mean	S.E.	C.V.
7	.73	.015	12.0	.43	.010	14.0
40	.73	.013	10.0	.43	.010	13.0
41	.76	.014	11.0	.45	.011	15.0
102	.83	.032	23.0	.38	.012	19.0
AUGUST						
7	.59	.017	18.0	.59	.017	18.0
40	.58	.013	13.0	.58	.013	13.0
41	.59	.011	13.0	.59	.013	13.0
102	.54	.011	12.0	.54	.011	12.0
SEPTEMBER						
7	.48	.010	12.0	.68	.019	16.0
40	.47	.011	14.0	.67	.015	13.0
41	.44	.008	11.0	.65	.013	12.0
102	.53	.010	12.0	.60	.015	15.0

Magnesium			
BOG	MEAN	S.E.	C.V.
JUNE			
7	.14	.003	12.0
40	.12	.002	12.0
41	.13	.004	16.0
102	.11	.003	16.0
AUGUST			
7	.15	.004	16.0
40	.14	.003	11.0
41	.14	.003	13.0
102	.13	.004	17.0
SEPTEMBER			
7	.17	.005	17.0
40	.16	.003	12.0
41	.14	.004	15.0
102	.14	.004	15.0

Table 14. Cation concentration (percent dry weight) of black spruce foliar tissue collected in September 1985.

BOG	MEAN	S.E.	C.V.
Potassium			
2	.50	.015	15.0
7	.57	.021	18.0
11	.40	.012	14.0
21	.55	.016	14.0
22	.51	.014	14.0
40	.52	.020	19.0
20	.53	.019	18.0
41	.61	.021	17.0
50	.55	.022	19.0
101	.43	.013	15.0
102	.45	.015	17.0
Calcium			
2	.26	.013	15.0
7	.20	.009	21.0
11	.30	.018	30.0
21	.27	.013	25.0
22	.25	.016	31.0
40	.22	.011	24.0
20	.25	.020	38.0
41	.14	.008	28.0
50	.25	.017	34.0
101	.21	.010	25.0
102	.22	.013	30.0
Magnesium			
2	.07	.002	15.0
7	.07	.002	15.0
11	.08	.003	18.0
21	.08	.002	13.0
22	.08	.002	14.0
40	.07	.002	12.0
20	.08	.003	18.0
41	.04	.001	12.0
50	.09	.003	15.0
101	.07	.003	25.0
102	.07	.002	11.0

NESTED ANALYSIS OF VARIANCE

Nested ANOVA's were conducted for each of three cations of three-leaved false Solomon's Seal for each sampling date. No significant treatment effects were detected in any of the analyses (Tables 15-17). In every analysis, however, both subgroup (Bog) and subsubgroups (plots within bog) effects were significant. An examination of the variance components reflects this heterogeneity among bogs. Between 30 and 55% of the variance is attributable to the subgroup (Bog) level of the analysis.

Nutrient content in foliar tissue is usually expressed as a percentage of dry weight. We initiated a pilot study to examine the variability in our data when nutrients were expressed on an area basis. Leatherleaf leaf area was determined before digestion and the number of leaves actually digested was also recorded. Mean nutrient content and the coefficient of variation was determined on a weight and area basis (Table 18). The coefficient of variation was still high when nutrients were expressed on an area basis and in fact slightly higher than mean nutrient content expressed on a weight basis.

The null hypothesis that there is no difference among ELF treatments was not rejected for any of the nutrient variables. However, the replicate bogs are heterogeneous for the three nutrient variables used. A large proportion of the variance was attributable to bogs and for samples collected within plots. The coefficient of variation was just as high when nutrient content was expressed on a leaf area basis as it was on a weight basis.

Table 15. Results of analyses of variance for cation content of *Smilacina trifolia* foliar tissue collected in June, 1985 (* significant at the 0.05 level or better).

Source of Variation	SS	df	F	Sign.
<u>K</u>				
Treatment	124.8	3	2.74	NS
Bog	106.2	7	21.11	*
Plot	109.4	55	3.92	*
Error	167.3	330		
<u>Ca</u>				
Treatment	.98	3	.15	NS
Bog	15.6	7	9.42	*
Plot	13.0	55	2.31	*
Error	33.6	330		
<u>Mg</u>				
Treatment	6.5	3	.70	NS
Bog	21.7	7	14.0	*
Plot	12.1	55	3.1	*
Error	23.8	330		

Percentage of total variance components

	K	Ca	Mg
Bog	32.7	30.8	45.2
Plot	22.1	12.5	14.0
Error	45.3	56.8	40.8

Table 16. Results of analyses of variance for cation content of *Smilacina trifolia* foliar tissue collected in July, 1985. (* significant at the 0.05 level or better).

Source of variation	SS	df	F	Sign.
<u>K</u>				
Treatment	98.6	3	2.18	NS
Bog	105.4	7	8.84	*
Plot	93.7	55	3.24	*
Error	173.7	330		
<u>Ca</u>				
Treatment	3.0	3	0.19	NS
Bog	37.0	7	18.76	*
Plot	15.5	55	2.51	*
Error	40.0	330		
<u>Mg</u>				
Treatment	2.8	3	0.56	NS
Bog	11.5	7	21.24	*
Plot	4.3	55	1.77	*
Error	14.5	330		

Percentage of total variance components

	K	Ca	Mg
Bog	33.9	49.8	46.8
Plot	18.0	10.1	6.0
Error	48.2	40.1	47.2

Table 17. Results of analyses of variance for cation content of *Smilacina trifolia* foliar tissue collected in August, 1985 (* significant at the 0.05 level or better).

Source of variation	SS	df	F	Sign.
<u>K</u>				
Treatment	120.0	3	2.20	NS
Bog	127.4	7	14.10	*
Plot	71.0	55	2.02	*
Error	210.5	330		
<u>Ca</u>				
Treatment	6.3	3	2.12	NS
Bog	67.2	7	9.59	*
Plot	22.6	55	2.57	*
Error	52.6	330		
<u>Mg</u>				
Treatment	6.5	3	2.17	NS
Bog	21.7	7	14.03	*
Plot	12.1	55	3.06	*
Error	23.8	330		

Percentage of total variance components

	K	Ca	Mg
Bog	38.6	55.9	45.2
Plot	8.9	9.2	14.0
Error	52.4	34.9	40.8

Table 1^d. Coefficients of variation for leatherleaf foliar nutrient content (per unit leaf area basis). Samples were collected in August 1985.

Bog	K	Ca	Mg
2	10.0	20.0	15.0
7	15.0	25.0	18.0
11	11.0	19.0	18.0
21	13.0	22.0	17.0
22	12.0	20.0	18.0
40	12.0	22.0	14.0
20	7.0	20.0	15.0
41	11.0	25.0	15.0
50	14.0	23.0	18.0
101	13.0	22.0	15.0
102	14.0	32.0	16.0

We still plan to use leaf area as a covariate in nested ANOVA's in an attempt to explain more of the variation found in our sampling design.

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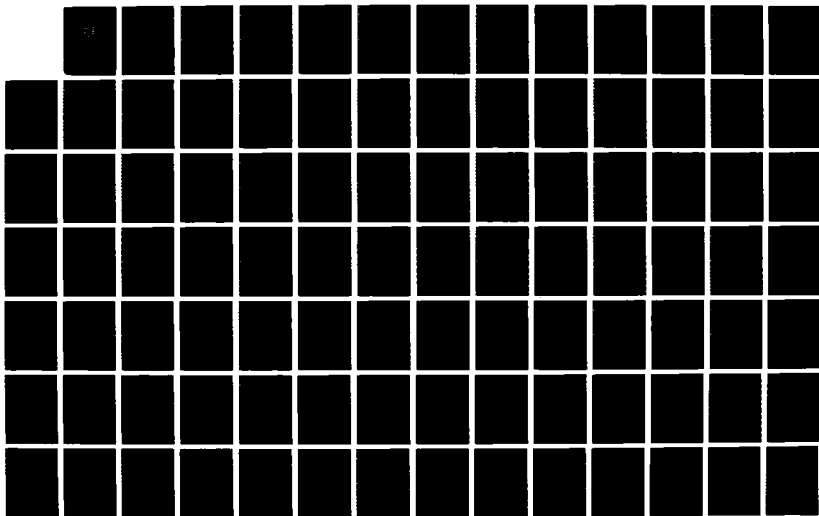
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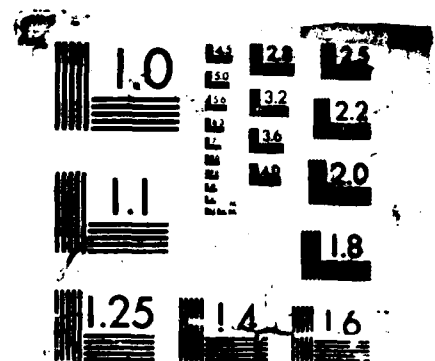
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MICROCOPY RESOLUTION TEST CHART

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APPENDICES
A-1 to A-5

APPENDIX A1. Water quality data for MAY, 1986
Values are means (S.E.)

BOG	TYPE	Temp	pH	Depth	Color	K25	K ⁺	Ca ⁺⁺	Mg ⁺⁺
2	1	14.5 (.28)	4.06 (.036)	0.7 (.24)	0.58 (.11)	25.3 (2.2)	.14 (.04)	1.32 (.22)	.27 (.06)
7	1	12.7 (.54)	3.96 (0.20)	3.1 (.55)	0.83 (.04)	32.4 (1.5)	.57 (.14)	0.93 (.07)	.22 (.02)
11	1	13.2 (.25)	4.02 (.036)	0.7 (.24)	0.67 (.08)	27.1 (1.9)	.35 (.05)	0.96 (.09)	.20 (.02)
21	2	13.0 (.42)	4.09 (0.26)	2.7 (.74)	0.73 (.06)	29.3 (1.6)	.18 (.07)	0.86 (.10)	.24 (.03)
22	2	13.5 (.17)	4.46 (.022)	5.7 (.21)	0.84 (.09)	20.7 (0.8)	.18 (.06)	1.75 (.37)	.41 (.04)
40	2	13.8 (.65)	4.24 (0.16)	1.3 (.42)	0.55 (.01)	21.6 (0.5)	.16 (.04)	0.88 (.07)	.22 (.01)

TYPE: 1= INTERMEDIATE 2= ANTENNAE 3= BACKGROUND 4= GROUND

DEPTH = Depth from peat surface to water table

K25 = Specific conductance corrected to 25 C

TEMP = Temperature in Centigrade

Appendix A 1
Page 2

BOG	TYPE	Temp	pH	Depth	Color	K25	K ⁺	Ca ⁺⁺	Mg ⁺⁺
20	3	13.9 (.30)	4.04 (.039)	3.0 (.51)	0.45 (.01)	23.1 (.13)	.10 (.06)	0.97 (.07)	.21 (.02)
41	3	13.0 (.04)	3.97 (.011)	6.5 (.61)	0.56 (.03)	27.9 (0.7)	.47 (.11)	1.31 (.12)	.14 (.01)
50	3	13.4 (.30)	3.97 (.029)	5.4 (.71)	0.63 (.03)	30.2 (1.3)	.23 (.04)	1.39 (.15)	.15 (.01)
101	4	13.6 (.35)	4.34 (.029)	0.7 (.50)	0.73 (.02)	20.0 (0.6)	.16 (.08)	1.71 (.07)	.34 (.01)
102	4	13.4 (.40)	4.27 (.019)	2.7 (.68)	0.65 (.02)	22.2 (0.6)	.07 (.01)	1.27 (.07)	.29 (.02)

APPENDIX A2. Water quality data for JUNE, 1986
Values are means (S.E.)

BOG	TYPE	Temp	pH	Depth	Color	K25	K ⁺	Ca ⁺⁺	Mg ⁺⁺
2	1	15.9 (.22)	4.05 (.01)	2.67 (.39)	0.66 (.11)	25.7 (1.9)	0.12 (.01)	1.53 (.33)	0.40 (.08)
7	1	14.6 (.37)	3.93 (.02)	8.00 (.20)	0.99 (.06)	33.5 (1.6)	0.47 (.15)	1.04 (.11)	0.32 (.03)
11	1	14.6 (.44)	3.85 (.02)	6.38 (.89)	0.78 (.07)	27.6 (2.4)	0.23 (.02)	0.89 (.04)	0.28 (.02)
21	2	15.0 (.29)	4.06 (.01)	8.07 (.79)	0.80 (.07)	29.9 (.91)	0.23 (.09)	0.79 (.11)	0.30 (.04)
22	2	15.0 (.17)	4.30 (.04)	9.93 (.44)	0.92 (.08)	22.0 (.98)	0.27 (.03)	2.00 (.30)	0.62 (.06)
40	2	15.5 (.30)	4.06 (.04)	4.33 (.78)	0.68 (.02)	24.0 (.45)	0.20 (.06)	0.98 (.07)	0.35 (.02)

TYPE: 1= INTERMEDIATE 2= ANTENNAE 3= BACKGROUND 4= GROUND

DEPTH = Depth from peat surface to water table

K25 = Specific conductance corrected to 25 C

TEMP = Temperature in Centigrade

Appendix A 2
Page 2

BOG	TYPE	Temp	pH	Depth	Color	K25	K+	Ca++	Mg++
20	3	15.5 (.31)	4.11 (.02)	1.43 (.28)	0.49 (.02)	24.4 (.33)	0.33 (.10)	0.64 (.07)	0.21 (.02)
41	3	14.8 (.32)	3.89 (.02)	5.65 (.40)	0.62 (.03)	29.0 (.87)	0.66 (.07)	0.77 (.09)	0.19 (.01)
50	3	15.6 (.32)	3.96 (.03)	4.40 (.73)	0.69 (.04)	34.0 (1.8)	0.38 (.14)	1.12 (.19)	0.23 (.01)
101	4	15.5 (.41)	4.16 (.06)	5.18 (.48)	0.78 (.02)	20.6 (.73)	0.46 (.08)	2.26 (.07)	0.62 (.01)
102	4	15.6 (.33)	3.88 (.03)	5.77 (.91)	0.78 (.03)	22.7 (.78)	0.52 (.05)	1.52 (.12)	0.51 (.04)

APPENDIX A3. Water quality data for JULY, 1986
Values are means (S.E.)

BOG	TYPE	Temp	pH	Depth	Color	K25	K ⁺	Ca ⁺⁺	Mg ⁺⁺
2	1	19.8 (.36)	4.08 (.03)	3.7 (.39)	0.11 (.006)	30.2 (1.53)	0.31 (.06)	1.02 (.19)	.32 (.04)
7	1	17.9 (.38)	3.88 (.01)	6.2 (.47)	0.13 (.002)	42.2 (2.51)	0.73 (.10)	0.89 (.06)	0.26 (.03)
11	1	18.2 (.28)	4.01 (.01)	4.3 (.91)	0.12 (.003)	37.3 (2.17)	1.07 (.50)	0.68 (.03)	0.18 (.02)
21	2	17.9 (.29)	4.04 (.02)	1.2 (.49)	0.12 (.003)	29.6 (1.59)	0.51 (.11)	0.84 (.03)	0.15 (.02)
22	2	18.7 (.06)	4.28 (.05)	0.3 (.30)	0.13 (.002)	28.4 (1.22)	0.45 (.04)	1.81 (.19)	0.34 (.03)
40	2	18.9 (.33)	4.18 (.02)	-1.6 (1.04)	0.12 (.001)	29.7 (0.71)	0.47 (.06)	0.79 (.08)	0.55 (.04)
20	3	17.0 (.31)	4.16 (.02)	-1.01 (.25)	0.10 (.002)	27.5 (0.39)	0.47 (.09)	0.84 (.02)	0.21 (.01)

TYPE: 1= INTERMEDIATE 2= ANTENNAE 3= BACKGROUND 4= GROUND

DEPTH = Depth from peat surface to water table

K25 = Specific conductance corrected to 25 C

TEMP = Temperature in Centigrade

Appendix A 3
Page 2

BOG	TYPE	Temp	pH	Depth	Color	K25	K ⁺	Ca ⁺⁺	Mg ⁺⁺
41	3	18.1 (.18)	4.02 (.01)	3.6 (.77)	0.08 (.001)	33.2 (1.06)	0.49 (.04)	1.31 (.12)	0.14 (.01)
50	3	17.1 (.58)	3.91 (.02)	1.6 (.67)	0.08 (.002)	36.8 (1.16)	0.64 (.02)	1.39 (.15)	0.23 (.01)
101	4	17.1 (.24)	4.40 (.01)	0.1 (.40)	0.08 (.001)	27.4 (1.11)	2.00 (.08)	1.71 (.07)	0.71 (.02)
102	4	17.6 (.38)	4.24 (.02)	0.6 (.95)	0.07 (.001)	27.6 (1.30)	1.23 (.10)	1.27 (.07)	0.48 (.06)

APPENDIX A4. Water quality data for AUGUST, 1986
Values are means (S.E.)

BOG	TYPE	Temp	pH	Depth	Color	K25	K+	Ca++	Mg++
2	1	16.2 (.06)	3.91 (.03)	-0.4 (.41)	0.80 (.10)	29.9 (1.7)	0.23 (.05)	1.32 (.22)	0.36 (.04)
7	1	14.1 (.18)	3.97 (.02)	7.6 (.58)	1.08 (.07)	38.3 (1.3)	0.40 (.09)	1.22 (.06)	0.29 (.02)
11	1	15.6 (.66)	3.96 (.02)	3.1 (1.1)	0.95 (.06)	34.5 (1.1)	0.24 (.13)	0.94 (.03)	0.22 (.01)
21	2	12.7 (.34)	3.85 (.02)	1.8 (.84)	0.89 (.06)	34.3 (0.8)	0.45 (.05)	0.95 (.11)	0.27 (.04)
22	2	15.2 (.10)	4.20 (.03)	-0.1 (.67)	1.20 (.09)	29.7 (1.2)	0.57 (.19)	2.33 (.19)	0.63 (.03)
40	2	14.8 (.16)	4.01 (.03)	0.4 (.28)	0.80 (.02)	29.4 (0.5)	0.43 (.07)	1.13 (.05)	0.38 (.02)
20	3	14.6 (.16)	4.01 (.03)	-0.6 (.67)	0.64 (.01)	27.6 (0.5)	0.11 (.03)	0.84 (.04)	0.22 (.01)

TYPE: 1= INTERMEDIATE 2= ANTENNAE 3= BACKGROUND 4= GROUND

DEPTH = Depth from peat surface to water table

K25 = Specific conductance corrected to 25 C

TEMP = Temperature in Centigrade

Appendix A 4
Page 2

BOG	TYPE	Temp	pH	Depth	Color	K25	K ⁺	Ca ⁺⁺	Mg ⁺⁺
41	3	15.0 (.13)	3.89 (.02)	3.4 (.58)	0.76 (.02)	34.3 (1.1)	0.40 (.17)	0.68 (.04)	0.19 (.01)
50	3	14.3 (.29)	3.84 (.03)	2.0 (.70)	0.80 (.03)	37.3 (1.4)	0.18 (.04)	0.92 (.09)	0.24 (.01)
101	4	15.0 (.41)	4.27 (.01)	0.3 (.48)	1.08 (.02)	27.6 (0.6)	0.28 (.05)	2.08 (.02)	0.73 (.01)
102	4	15.1 (.20)	4.16 (.02)	0.3 (.44)	0.98 (.02)	29.3 (0.9)	0.44 (.14)	1.58 (.04)	0.56 (.04)

APPENDIX A5. Water quality data for SEPTEMBER, 1986
Values are means (S.E.)

BOG	TYPE	Temp	pH	Depth	Color	K25	K ⁺	Ca ⁺⁺	Mg ⁺⁺
2	1	11.0 (.15)	3.93 (.04)	-1.23 (.53)	0.72 (.07)	33.6 (1.9)	0.31 (.05)	1.01 (.13)	0.38 (.03)
7	1	10.4 (.10)	3.81 (.01)	-0.42 (1.18)	0.98 (.05)	40.8 (1.7)	0.51 (.12)	0.87 (.03)	0.32 (.02)
11	1	10.8 (.11)	3.84 (.03)	0.55 (.65)	0.90 (.07)	38.4 (1.3)	0.36 (.10)	0.74 (.03)	0.24 (.01)
21	2	10.5 (.12)	3.95 (.02)	0.92 4.52	0.82 (.05)	34.4 (0.79)	0.43 (.10)	0.64 (.06)	0.28 (.03)
22	2	11.0 (.16)	4.08 (.04)	-0.50 0.45	1.16 (.08)	28.1 (0.87)	0.18 (.04)	1.74 (.14)	0.68 (.06)
40	2	11.0 (.08)	4.01 (.02)	0.20 0.30	0.72 (.02)	29.4 (0.51)	0.26 (.05)	0.84 (.04)	0.39 (.01)
20	3	10.9 (.07)	3.74 (.02)	-2.00 (.65)	0.63 (.01)	31.4 (0.72)	0.27 (.04)	0.64 (.01)	0.25 (.01)

TYPE: 1= INTERMEDIATE 2= ANTENNAE 3= BACKGROUND 4= GROUND

DEPTH = Depth from peat surface to water table

K25 = Specific conductance corrected to 25 C

TEMP = Temperature in Centigrade

Appendix A 5
Page 2

BOG	TYPE	Temp	pH	Depth	Color	K25	K+	Ca++	Mg++
41	3	11.2 (.09)	3.73 (.01)	1.20 (.73)	0.71 (.01)	38.2 (0.98)	0.44 (.17)	0.68 (.05)	(0.23) (.02)
50	3	11.1 (.12)	3.68 (.02)	0.30 (.71)	0.72 (.02)	40.5 (1.15)	0.25 (.04)	0.64 (.05)	(0.25) (.02)
101	4	10.6 (.11)	4.27 (.02)	-0.28 (.08)	0.93 (.03)	30.3 (0.49)	0.47 (.05)	1.59 (.04)	(0.65) (.02)
102	4	10.8 (.11)	4.16 (.01)	-0.12 (.31)	0.92 (.04)	31.7 (1.05)	0.66 (.15)	1.21 (.04)	(0.54) (.02)

ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM:

BIRD SPECIES AND COMMUNITIES

ANNUAL REPORT: 1986

SUBCONTRACT NUMBER: EO6549-84-011

JoAnn M. Hanowski

Gerald J. Niemi

John G. Blake

Natural Resources Research Institute

University of Minnesota, Duluth

Duluth, Minnesota 55811

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ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM:

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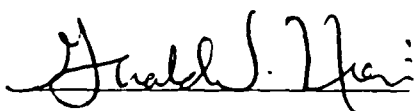
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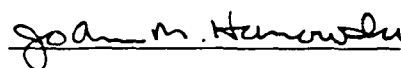
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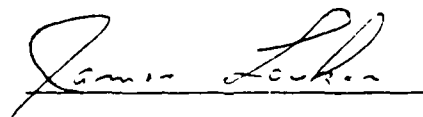
Duluth, Minnesota 55811



Gerald J. Niemi
Co-principal Investigator



JoAnn M. Hanowski
Co-principal Investigator



Jim Loukes
Senior Grant Administrator

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ABSTRACT

This report summarizes 1986 research activities for studies to identify effects of ELF electromagnetic fields on bird species and communities in Wisconsin and Michigan. We expanded our monitoring program this year to include bird censuses over a five month period from May to September. In addition, we initiated a detailed habitat assessment of all control and treatment transects in Wisconsin because there are no pre-impact data available for that state. These data will allow us to pair control and treatment areas on the basis of habitat characteristics in future analyses.

In addition to ANOVA used for common species, three types of data were examined in our comparisons of less common species; frequency of occurrence (number of transects where a species was recorded), number of individuals observed, and a prominence value which is a product of the two. The prominence values were more conservative than number of individuals but more liberal than frequency of occurrence and were used for interpreting differences between control and treatment transects.

Most species and individuals were observed in May and June in both states. The number of observations then decreased over the summer months (July and August), but increased slightly during fall migration (September) on both control and treatment transects and in both states. In Michigan, more species and individuals were observed on control than on treatment transects in both May and September. In contrast, only one community-level parameter in Wisconsin was different between control and treatment areas; more individuals were observed on control transects in the breeding season.

Three summer resident species (Nashville Warbler, Red-eyed Vireo, and Ovenbird) were the most common species on both control and treatment

transects throughout the spring, breeding, and late-breeding seasons in both states. A permanent resident species, the Black-capped Chickadee, was the most abundant species during early and late-migration periods in both states. We made 122 species-specific comparisons between control and treatment areas in Wisconsin where the antenna system has existed since 1969. Five species were observed consistently more often on control transects, four species more often on treatment transects, and four species showed no consistent pattern of abundance among seasons. In Michigan where the antenna is not yet operating but the right-of-way (ROW) exists, 133 species-specific comparisons were made. In this state, seven species were observed consistently more often in control areas, two species were observed more often in treatment areas, and eight species showed no consistent pattern of abundance among seasons.

Arrival times of each species in control and treatment areas for each state were recorded and results indicated different patterns in Michigan and Wisconsin. In Michigan, more long-distance migrants and more vireo and warbler species were observed in control areas before treatment areas. In Wisconsin, more total and short-distant migrant species were recorded in treatment areas before control areas.

Most comparisons between 1985 and 1986 bird observations indicated that fewer individuals and fewer species were observed in 1986 than in the 1985 breeding season (June). Decreases in total number of birds observed could be explained by large decreases of a few species. The Ovenbird, Red-eyed Vireo, and Nashville Warbler showed the greatest declines in abundance in both control and treatment transects and in both states. Three species increased by more than 25 individuals in Wisconsin between 1985 and 1986 but no species in Michigan showed an increase of this magnitude.

Several tests were computed to examine possible effects of the ROW on bird species and communities in treatment areas. Bird distribution (all species) in relation to the transect center line indicated that birds on control transects were not distributed randomly. The Indigo Bunting was the only species that indicated a possible attraction to the antenna ROW based on greater number of observations of this species adjacent to the ROW.

In comparisons of observers, only one difference in twelve was detected between two observers who simultaneously (separated by 10 minutes) censused eight transect segments. In this test, more Ovenbirds were recorded by the first observer.

Habitats were classified into 19 types at 25 m intervals along control and treatment transects in Michigan. Control transects had more maple and cedar habitats and treatment transects had more lowland conifer habitat. However, no differences were detected when broader habitat categories were used.

INTRODUCTION

Effects of extremely low frequency (ELF) electromagnetic (EM) fields on most aspects of a bird species' life history are poorly understood (National Academy of Sciences 1977; Lee et al. 1979). Birds use the earth's magnetic fields to aid in their navigation during migration (Emlen 1975; Beason and Brennan 1986) and magnetic fields produced by the ELF communications system may affect their navigation abilities. Some investigations have reported that orientation of Ring-billed Gull (Larus delawarensis) chicks (Southern 1972; 1975) and migrating birds (Larkin and Sutherland 1977) were disrupted by the ELF antenna in Wisconsin. However, Williams and Williams (1976) found no evidence of attraction or repulsion of migrating birds in relation to the antenna during any mode of operation. Behavioral and physiological effects of domestic birds exposed to ELF fields have been studied in the laboratory (Krueger et al. 1972; Durfee et al. 1976) and environmental studies of a native bird species are currently underway at the ELF antenna site in Michigan (Beaver et al. 1985).

In contrast to studies that have focused on assessing effects on individuals of one or a few species, several investigators have studied the effects of transmission lines on bird communities. These include: (1) combined effect of habitat changes and EM fields (Anderson et al. 1977; Anderson 1979; Dawson and Gates 1979; Meyers and Provost 1979; Stapleton and Kiviat 1979; Bell 1980; Bramble et al. 1984; Niemi and Hanowski 1984); (2) right-of-way (ROW) edge (Chasko and Gates 1982; Kroodsma 1982); (3) collision with lines (Beaulaurier et al. 1982); and (4) audible noise generated by a transmission line (Lee and Griffith 1978). However we are unaware of any investigations that have attempted to separate effects of EM

fields from effects due to habitat changes along the ROW on bird species and communities.

This investigation was designed to isolate effects of EM fields produced by the ELF antenna systems on bird species and communities breeding in and migrating through Wisconsin and Michigan. In this report we summarize our research activities for 1986, our third year of participation in the ELF ecological monitoring program. Progress in the previous two years included: (1) selection, measurement, and modifications or reselection of study areas to insure that all met the required EM field ratios; (2) bird censuses of fall migration (1984) and breeding (1985) bird populations; and (3) reassessment of study design and statistical analyses.

We expanded our monitoring program in 1986 to include censuses over a five month period from May to September. With our sampling scheme we were interested in whether the ELF antenna system affected populations of birds migrating or breeding in proximity to the antenna systems relative to those away from the systems. Our questions of interest were: are there differences in (a) bird species richness; (b) bird community density; (c) density of a relatively common bird species; or (d) relative frequency of uncommon species between treatment transects (those adjacent to the ELF antenna system) and control transects (those away from the influence of the ELF EM fields)? Characteristics of the bird community were examined for each of five periods: (1) spring migration (May), (2) early breeding (June), (3) late breeding (July), (4) early fall migration (August), and (5) late fall migration (September).

There are two potential approaches for assessing effects of the ELF antenna on bird species and communities: (1) compare the affected area (treatment) with a similar control area; or (2) conduct a before-and-after type study. Because the antenna is not yet operating in Michigan, a

before-and-after investigation is planned. In Wisconsin, the antenna has been operating periodically since 1969 but no pre-impact data are available. However, we cannot assume that the antenna system has not already altered the bird community in this area. Consequently, we cannot pair transect segments based on similarities in bird species communities (number one above), but we can pair control and treatment transect segments on the basis of similar habitat features or account for habitat differences between control and treatment areas. This year we initiated a detailed quantitative habitat assessment of our study areas in Wisconsin to document habitat differences and similarities between control and treatment transects. Our rationale for using this method is that birds select their breeding areas on the basis of vegetation structure (Lack 1933; Hilden 1965; James 1977) and, therefore, areas of similar vegetation should also have similar bird communities. Although the study design in Wisconsin is not as desirable as the before-and-after design in Michigan, studying potential effects in Wisconsin in concert with Michigan provides further insight on the potential long-term effects of the antenna on bird species and communities.

EXPERIMENTAL DESIGN

The first step in the experimental design was to examine techniques available for quantifying bird community parameters and the sample sizes required to detect a specified difference between control and treatment areas. Four potential approaches were examined: transect counts, point counts, territorial mapping, and mist-netting (Table 1). Use of territorial mapping and mist-netting can be disregarded for use in this study because of the amount of effort required to obtain statistically reliable results. Transect and point counts are closely related techniques that differ

Table 1. Comparison of statistics for four bird census methods using the number of species as the community parameter of interest. Difference detectable was assumed to be 15% of the mean and determination of sample size necessary to detect that difference was based on a probability of 0.05 and a power of 80% (Snedecor and Cochran 1967, p. 113. Formula used was: $n = (15.8 \times S^2)/d^2$ where d=the absolute difference detectable or 15% of the mean (Snedecor and Cochran 1967). Statistics were estimated for forested habitats in the upper-midwestern United States based on the authors personal data.

Method	Mean number of species	Variance	Absolute difference detectable	N	Effort per n in hr	Initial effort per n in hr	Total effort in hr
Point count ¹	6.0	10.0	0.90	195	0.25	0.60	169
Transect count ²	12.0	8.0	1.30	39	0.60	3.00	144
Territory ₃ mapping	18.0	25.0	2.70	54	16.00	16.00	1728
Mist-netting ⁴	1.6	1.8	0.24	494	0.50	0.25	371

¹ Estimates are for all species observed during 10 min count period.

² Estimates are for the number of species observed during a 30 min census of a 500 m transect.

³ Estimates are for the total territorial males mapped in a 12.5 ha area.

⁴ Estimates are for the number of species caught in a 12 m mist-net during a 5 hr period.

primarily in whether the observer is moving (transects) or stationary (point counts) and in the size (area) of the experimental unit. In our comparison between methods, we assumed that we would census an area 100 m from the point or transect line (both sides). The point count method would result in an effective census area of about 6.28 ha (assuming two point counts completed in the same time as one 500 m transect) and the transect about 10 ha. We chose transect counts for use here because the ELF communications system consists of a long, linear network of the antenna and ROW and transects could be run parallel to this network. Point counts also could have been run adjacent to this network, but because we would walk along the swath adjacent to the ELF network, we decided to use the method that would include the larger census area (transects). In addition, if our estimates of the mean and variances are correct, transect counts are slightly more efficient in terms of effort (Table 1).

In an ideal experimental design, each segment should be randomly assigned to control and treatment areas. However, from the perspective of censusing in the field, this arrangement would be inefficient. To compromise statistical rigor with the practicalities of working in the field, we decided to group eight 500 m segments into one long transect line (hereafter called transect). Each segment was separated by a buffer of 50 m to reduce autocorrelation between the experimental units (Figure 1). We grouped eight segments because our previous experience indicated that bird censuses should be completed from one half hour before sunrise to about four hours after sunrise. A total of 4 hours and 35 minutes are needed to census eight segments and seven buffers (30 minutes for each segment and 5 minutes for each buffer). We estimated that 39 segments (Table 1) were needed in each group (control and treatment for each state) to detect a 15%

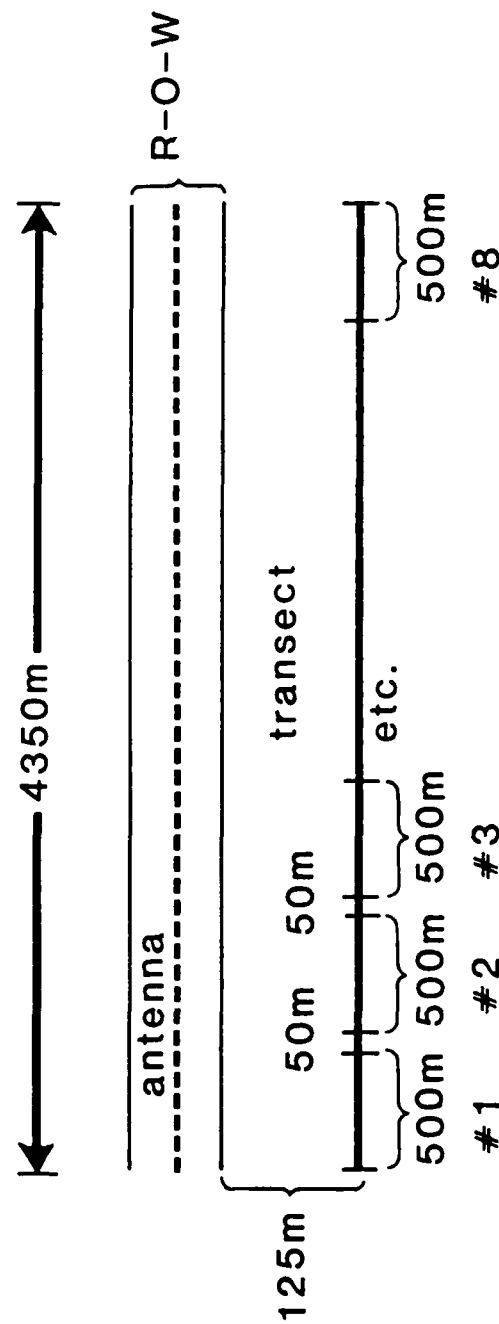


Figure 1. Schematic of a treatment transect layout ROW = right-of-way.

difference in number of species. This percent difference was selected based on the ability to detect a difference of one species between control and treatment areas. Therefore, we selected five transect starting points per group or a total of 160 segments (40 segments per group).

Placement of treatment transects with respect to the ELF antenna system was designed to achieve two goals: (1) to reduce or eliminate potential effects of the ROW edge on the bird community (Chasko and Gates 1982), and (2) to maintain an appropriate EM field within the treatment area. We placed the transects parallel to and 125 m from the edge of the ELF antenna ROW (Figure 1). This achieved a 25 m buffer from the limits of where we recorded birds (100 m) from the ROW edge. Although this placement reduced the intensity of EM fields within treatment areas, EM fields were still high enough to achieve the 10:1 ratio between treatment and control areas required in the study specifications (Brosh et al. 1986).

STUDY AREAS

Starting locations for 10 control and 10 treatment transects were randomly selected in Michigan and Wisconsin (Figures 2 and 3) with methods described previously (Niemi and Hanowski 1986). Electromagnetic fields were measured to insure that 76 Hz EM fields at a treatment site were significantly larger than: (1) 76 Hz EM fields at control sites, (2) 60 Hz fields at treatment sites, and (3) 60 Hz fields at control sites. In addition, the exposure criteria required that there was no substantial difference in the ambient 60 Hz EM fields between control and treatment transects (Brosh et al. 1986). Electromagnetic fields were measured at the beginning and ending points for each transect; they were not completed for each transect segment because most were not easily reached (e.g., most are

Figure 2. Location of Wisconsin antenna and study transects.

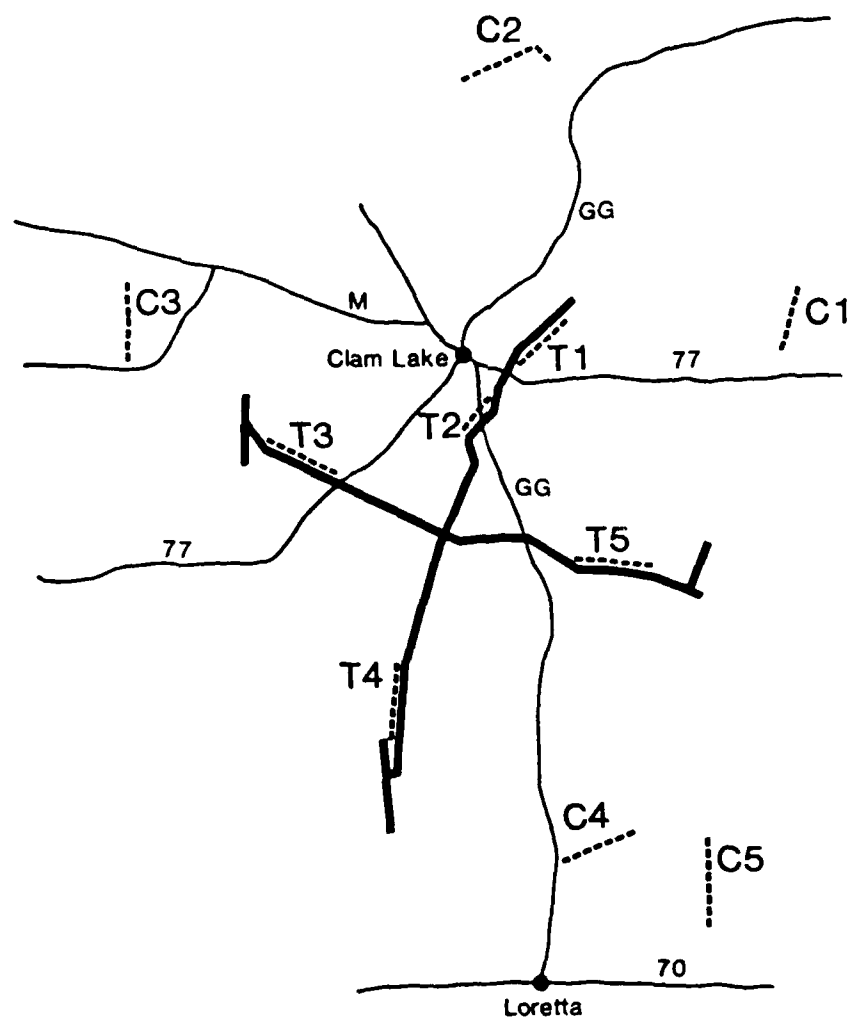
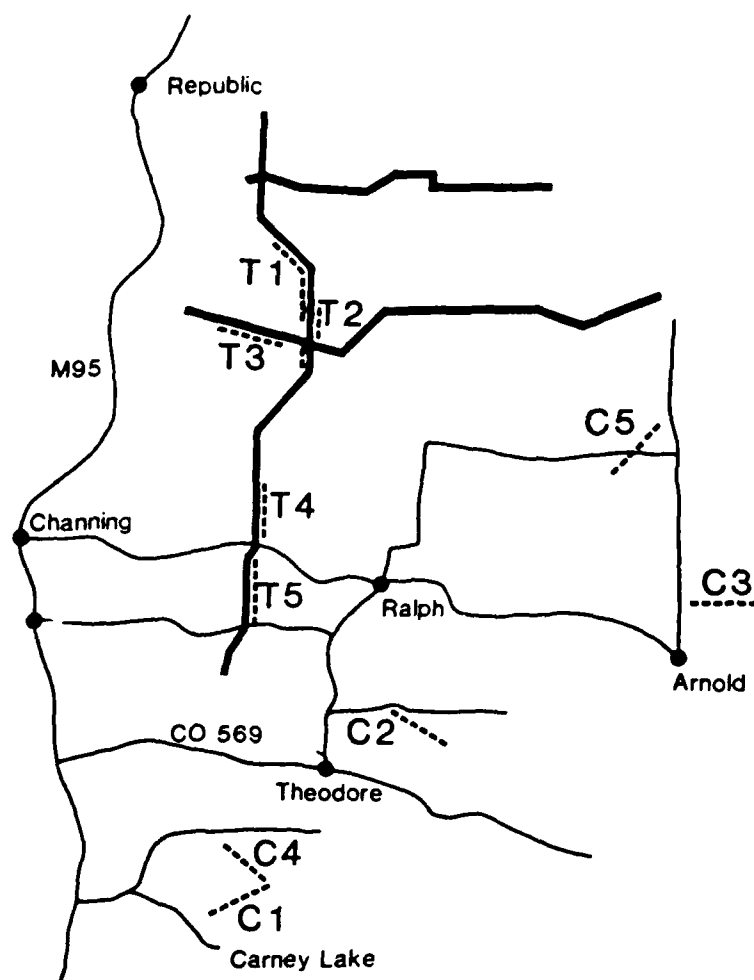


Figure 3. Location of Michigan antenna and study transects.



1-4 km from a road). All transects satisfy the EM exposure criteria and will be used for the remainder of the monitoring period.

Information regarding proposed logging along the transects was obtained from Department of Natural Resources in Michigan and the U.S. Forest Service in Wisconsin. Five control and five treatment transect segments are scheduled for logging in Michigan effective through 1990 (Table 2). In Wisconsin, two control and eight treatment transect segments will be affected; however, all of these sites will be selectively cut or thinned (Table 2). Because of the length of our transects, it is probably impossible to avoid areas affected by logging. We will be sensitive to disturbances along transects in subsequent analyses and if necessary, affected transect segments can be removed from analyses. This will allow us to assess potential affect of logging or other disturbances on results of the investigation.

METHODS

Bird censuses. Each segment was censused five times in 1986. Census one was completed in early May to document spring migration and arrival dates of bird species in the study areas. Breeding bird data were collected in June (early breeding) and July (late breeding). Censuses four and five were completed in August and September during the fall migration of birds through the study areas.

We used the line transect method to census all transects (Emlen 1971, 1977; Jarvinen and Vaisanen 1975). Census data were gathered during morning hours (one half hour to four and one half hours after sunrise) on days when wind speed was < 15 km/hr and with little or no precipitation. Control and treatment transect segments were censused simultaneously by two observers to eliminate differences that could occur by censusing at

Table 2. Summary of Michigan and Wisconsin transect locations and proposed logging of study areas effective through 1990.

Number and Name	Township	Range	Sections	Number of 500 m transect segments affected
MICHIGAN				
C1 Carney Lake	41N	29W	33,34,35,36	2
C2 Skunk Creek	42N	28W	14,23,24	2 (thinning)
	42N	27W	19,30	
C3 Arnold	43N	25W	31,32,33,34	0
C4 Lost Lake	41N	29W	21,26,27,28,35	1
C5 Bob's Creek	44N	26W	13,23,24,26	0
T1 Heart Lake	45N	28W	7,18	1
	46N	29W	1	
T2 Flat Rock Creek	44N	28W	6	3
	45N	28W	19,30,31	
T3 Schwartz Creek	45N	28W	31	1
	45N	29W	26,27,35,36	
T4 Turner Road	43N	29W	1,11,12	0
	44N	29W	36	
T5 Leeman's Road	43N	29W	14,23,26,35	0
WISCONSIN				
C1 Spillerberg Lake	43N	3W	23,26,35	0
C2 Mineral Lake	44N	4W	15,16,17,18	0
C3 Rock Lake	42N	6W	6	1 (thinning)
	43N	6W	19,30,31	
C4 Blaisdell Lake	40N	4W	13,14,22,23	0
	40N	3W	18	
C5 Brunette River	40N	3W	16,21,28	1 (thinning)
T1 Woodtick Lake	43N	4W	22,23,27,28,33	0
T2 Little Clan Lake	42N	4W	5,8,17	3 (thinning)
T3 Christy Lake	42N	5W	7,8,15,16,17	2 (thinning)
T4 Black Lake	41N	5W	24,25,36	0
T5 Moose River	42N	3W	31	3 (thinning)
	42N	4W	35,36	

different time periods. Censuses of control and treatment transects were randomly assigned to each of two observers (Hanowski and Blake) with the restriction that each observer census the same number of control (80) and treatment (80) segments in each census period. This was done to control for potential differences in observers. An exception to this was when a third observer (Niemi) was used in Wisconsin in June so that two observers (Hanowski and Blake) could simultaneously census one transect to document observer variation.

A total of eight transect segments were censused by each observer daily. Each observer walked the designated transect segment at a rate of 16.7 m/min and recorded the following information for each bird observed: (1) species; (2) sex when possible; (3) behavior (e.g., singing or calling); (4) estimated perpendicular distance from the transect in meters; (4) relative position to the transect (e.g., right or left side); and (5) distance along the transect in meters from the start. Information for each individual bird observed was recorded on microcomputer files directly from field sheets. Individual birds flying over the area (e.g., above the canopy) were not included in the data file.

We used the number of individuals observed up to 100 m from the transect in all data analyses instead of attempting to calculate a density value. Relative density could be calculated with a variety of formulae (Emlen 1971, 1977; Jarvinen and Vaisanen 1975; Burnham et al. 1981) but at the present time we have no basis for using one formula over another. We only assume that the number of birds recorded is related with the density of birds in an area. A disadvantage to using a density formula such as LINETRAN (Burnham et al. 1981) is the number of observations required to obtain a reliable density estimate. For example, at least 30 observations/species are recommended to calculate densities with the

Fourier series estimator. This is prohibitive in this study because we do not observe this many individuals of one species on a 500 m segment. To obtain the specified sample, our segments would have to be about five times longer (about 2500 m) than they are now. This design is not feasible because of the large sample size (number of segments) needed to detect the desired difference between control and treatment areas. It may be possible to use this technique at a later date if we pool data among years or among different experimental units.

Another advantage of our method of using the total number of observations is that we eliminate the potential variability between observers to estimate distance (Svensson 1977). Here we only assume that the ability to detect individuals is similar between observers and therefore between control and treatment sites because each observer censuses the same number of control and treatment segments.

Bird guilds. We listed all bird species observed in Michigan and Wisconsin and all species that could potentially occur in our study areas. Each species was classified in four different ways: (1) nesting area, (2) food or foraging type, (3) habitat preference, and (4) migration type (Appendix 1). Classifications were based on published sources (e.g., Martin et. al. 1951; Bent 1963, 1964; Green and Niemi 1978; Terres 1982; AOU 1983, 1985). A hierarchical classification scheme was used if a species occurred in more than one category. When this occurred, we identified primary, secondary, and tertiary areas of use for these species; primary being the predominant category of use. We will use this information in future analyses to address any differential affects of the ELF antenna on species that use particular feeding strategies, specific nesting areas, or different migration patterns (see Verner 1984). These analyses will allow us to test for

differences between control and treatment transects for species that have similar life history characteristics and therefore, similar exposures to ELF EM fields.

Wisconsin vegetation. The vegetation on all 80 control and treatment segments will be measured over a two year period (1986 and 1987). A two year period was selected to more efficiently use personnel and to better control for seasonal variation in vegetation growth. A representative portion of segments measured in 1986 will be remeasured in 1987 to quantify annual differences in vegetation growth. If differences exist, they will be accounted for in the final data analyses and when we match control and treatment segments.

Vegetation samples were collected at 25 m intervals to describe changes that occur within each segment. Sample points were positioned two meters from the transect line to avoid biases in where the flag markers for the transects were placed. We used methods that we have successfully used in past investigations to assess habitat characteristics (Niemi and Hanowski 1984; Niemi 1985) which were modified from Wiens (1969) and Wiens and Rotenberry (1981). Densities of trees, shrubs, forbs, and graminoids will be calculated with the point-centered quarter method (Cottam and Curtis 1956). Vegetation variables measured and their description are shown in Appendix 2. All vegetation data were entered onto microcomputer files.

Michigan vegetation. We classified habitats of the Michigan study areas at 25 m intervals along each segment. Nineteen habitat types were used for classification (Appendix 3) and percentage of occurrence of each type on control and treatment areas was calculated. We did this to identify gross habitat differences between control and treatment transects and to

potentially explain differences in bird populations between control and treatment transects. For example, because the antenna has not operated in Michigan we would expect that any differences between control and treatment transects can be explained by another source of differences between these areas. We observed differences in 1985 and contend that these differences were due in part to differences in habitats between control and treatment transects. We collected 1750 vegetation samples in Michigan and entered these data onto microcomputer files. A chi-square test was used to test for differences between control and treatment transects using the proportions of the 19 habitat types observed.

STATISTICAL ANALYSES

Variable selection and within season analyses. All data entered on microcomputer files were checked for accuracy by someone other than the original data entry person. Species lists and number of observations of each species for each segment were tabulated with Statistix program for microcomputers (NH Analytical Software 1986). We used the same criteria for selecting variables for parametric statistical analysis that we identified in 1985 (Niemi and Harowski 1986). Briefly, we included: (1) those species with a mean of more than one observation per 500 m segment in control or treatment areas of either state in any season; (2) mean number of species observed in a 500 m segment in control or treatment areas of either state during each season; and (3) mean number of individuals observed in a 500 m segment in control or treatment areas of either state and during each season. We tested for differences between control and treatment transects with SPSS sub-program ONEWAY (Nie et al. 1981). All variables used in parametric statistical tests were examined for assumptions of normality and homoscedasticity of variance prior to statistical analyses (Sokal and Rohlf

1981). Skewness and kurtosis were calculated with SPSS subprogram CONDESCRIPTIVE to examine the normality of each variable and Bartlett's test for homogeneity of variances was calculated using SPSS subprogram ONEWAY. Several variance-stabilizing and normalizing transformations (e.g., square root and logarithmic) were calculated for variables that did not meet these assumptions. We used logarithmic (natural) transformations in final analyses because they were consistently best for reducing skewness, kurtosis, and heterogeneity of variances.

A second group of less common species was chosen based on frequency of occurrence. These species had to be present on at least six total control and treatment segments with the restriction that they occur on at least five control or five treatment transect segments within each state for each season (e.g., a species was not included if it occurred on three control and three treatment segments). These species were tested with a G-test or Fisher exact test (Sokal and Rohlf 1981) between control and treatment transects for: (1) number of segments the species was observed, (2) total number of individuals observed, and (3) a prominence value; equals to the square root of the product of relative frequency of species occurrence (1 above) and number of individuals observed (2 above). In 1985 we tested for differences in only the number of transect segments where a species was observed (Niemi and Hanowski 1986). This year we included the test between number of individuals observed simply to account for the absolute number of individuals observed between control and treatment areas. For example, the test for frequency of occurrence on transect segments (number 1 above) could be misleading because a species could occur on fewer control segments even though more individuals may have been observed on control segments. The prominence value (number 3 above), however, weighs both the frequency of occurrence and number of individuals (Beals 1960; Blake 1982). All

three measures have merit, so we included results of statistical tests from all.

Annual differences in breeding bird numbers. We chose number of species, number of individuals, and those species that occurred with a density of > one individual/500 m segment in either the 1985 or 1986 June breeding bird census. A two-way ANOVA was computed to test for annual differences and treatment effects for these variables.

Observer variation. A paired t-test was used to assess observer variation in bird observations for data gathered almost simultaneously (\pm 10 minutes) by two observers on eight transect segments during June in Wisconsin. In this census, observer two (Blake) started 10 minutes after observer one (Hanowski) to control for potential effect of observers on each other. We tested for differences between observers for number of individuals, number of species, and for common species (mean > 1 individual/500 m segment).

Spring arrival dates. A numeric code (1 to 5) was assigned to each species observed during the May spring migration census in each state. These codes corresponded to the five days in sequence that were needed to census all transects in each state. We tabulated the number of species observed first on control and number observed first on treatment transects in each state and tested the frequency of occurrence (first versus second) with a G-test. Separate tests were computed for: (1) all species, (2) permanent resident species, (3) short-distance migrant species, (4) long-distance migrant species, and (5) vireo and warbler species for each state. For these tests, a species could be included in more than one category.

Edge effect. We designed our treatment transects to reduce edge effects by not including the ROW and the 25 m adjacent to the ROW in our census belt. However, it is possible that the "edge" penetrates beyond the 25 m we allowed for in our study design. We addressed this problem by examining the lateral distribution of birds observed in relation to the transect center line and to the ROW for all individuals and for those species that had more observations in treatment areas as compared with control areas for any statistical tests ($P < 0.05$) for any season and for each state. A G-test was used to test for differences in the total number of observations on the right or left side of the transect center line for control segments or between number of observations adjacent to versus opposite the transect center line from the ROW for treatment segments. For more abundant species and for the total number of individuals observed, each observation was classified into 25 m intervals (4 on each side). The distribution in corresponding belts on either side of the transect center line were compared with a chi-square contingency table. This test was used when there were at least five individuals observed within each cell.

RESULTS

To simplify and condense the results section, we eliminated all probability (P) values. Any difference stated in this section was significant to at least the $P < 0.05$ level. Three separate non-parametric tests were computed for uncommon species: frequency of occurrence on segments, number of individuals, and a prominence value (see methods). Results for all three tests are presented in the tables, but we chose to interpret only results from the prominence values. Our reasoning was simply because the prominence values were more conservative than the test for individuals but more liberal than the test of frequency. Therefore, prominence values

represent a compromise between the test for individuals and the test for frequency of occurrence.

Spring Migration Bird Censuses

Michigan. Seventy-six species and 2159 individuals were observed on all transect segments in Michigan during the spring migration census (Appendix 4a). Sixty-nine species and 1210 individuals were recorded on control segments and 54 species and 949 individuals were counted on treatment segments (Appendix 4A, Table 3). The Nashville Warbler was the most common species recorded on both control and treatment segments (Table 3). All significant differences (3 of 12 ANOVA and 7 of 24 non-parametric tests) between control and treatment transects indicated that more birds were observed on control than treatment segments (Tables 3 and 4).

Similar to the above pattern, there was a tendency for more species, particularly long-distance migrants and vireos and warblers, to be observed first on control transects (Table 5). As expected there was no difference in the number of permanent residence species to be observed first on either control or treatment transects (Table 5).

Wisconsin. Seventy-eight species and 2848 individuals were observed on all control and treatment transects in Wisconsin during the spring migration census (Appendix 4b). Sixty-two species and 1452 individuals were observed on control and 67 species and 1396 individuals were observed on treatment transects (Appendix 4B, Table 3). The Nashville Warbler and Ovenbird were the most common species on both control and treatment transects (Table 3). In the ANOVA, average number of observations of two species were higher on control than on treatment segments (Table 3). In addition, prominence values differed for four of 24 species tested with non-parametric tests

Table 3. Mean observations in a 500 m segment and significance of one-way ANOVA between control (C) and treatment (T) segments for the May spring migration period in Michigan and Wisconsin.

Parameter	Michigan		Wisconsin	
	T	C	T	C
Least Flycatcher ^{1,2}	0.4	1.1	0.5	1.3
Blue Jay	1.3	1.5	1.2	1.1
Golden-crowned Kinglet	1.0	0.5		
American Robin	1.0	1.1		
Red-eyed Vireo			1.7	1.8
Nashville Warbler	5.4	5.2	6.1	6.1
Northern Parula ²			0.3 **	1.1
Chestnut-sided Warbler ²			2.0	1.6
Yellow-rumped Warbler	1.6	0.9		
Black-throated Green Warbler	1.9	2.4	2.0	2.4
Black-and-white Warbler			1.0 *	1.9
Ovenbird	1.4 *	2.5	4.8	6.3
Common Yellowthroat ²			1.1	0.7
White-throated Sparrow	2.1	1.4	2.4	2.0
Individuals ²	23.7 **	30.3	34.9	36.3
Species	9.7 **	12.9	13.4	12.8

* $P < 0.05$; ** $P < 0.01$

¹Log transformed in Michigan analysis

²Log transformed in Wisconsin analysis

Table 4. Species showing significant differences during May 1986 between control and treatment transects. Species were examined for differences in number of control (C) and treatment (T) transects the species occurred on, in total number of individuals recorded on control and treatment transects, and in prominence value (see text) for that species on control and treatment transects. Species are included only if they occurred on at least 6 control or treatment transects. Differences are tested with a G-test or with a Fisher Exact test when $N=0$ (Sokal and Rohlf 1981).

Species	Michigan						Wisconsin					
	Transect		Individual		PV		Transect		Individual		PV	
	T	C	T	C	T	C	T	C	T	C	T	C
Yellow-bellied Sapsucker	6	14	10 *	21	3.9 *	12.4						
Brown Creeper	2	7	2 *	10	0.4	4.2						
Winter Wren	12	21	15 *	32	8.2 **	23.2						
Northern Parula	0 *	6	0 **	10	0	3.9						
Magnolia Warbler							8 *	1	9 **	1	4.0 *	0.2
Cape May Warbler							11 *	2	16 ***	2	8.4 **	0.4
Black-and-white Warbler	10	18	17 *	34	8.5 *	22.8						
Rose-breasted Grosbeak	2 ***	17	2 ***	36	0.4 ***	23.4	4 *	14	5 ***	26	1.6 ***	15.4
Chipping Sparrow	7 *	19	11 **	30	4.6 ***	20.7						
Song Sparrow							12	5	21 *	9	11.5 *	3.2
Red-winged Blackbird	0 **	8	0 ***	41	0 ***	18.3						
Brown-headed Cowbird	6	14	8 *	20	3.1 *	11.8						
Number of Species Tested					24						24	

* = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$

Table 5. Comparison of species arrival times on control and treatment transects in Michigan and Wisconsin during spring migration, May 1986.

Group Tested	Number of species seen first on	
	Treatment	Control
Michigan		
All species	20	34
Permanent residents	5	8
Short-distance migrants	10	12
Long-distance migrants	5 *	14
Vireos and warblers	2 *	10
Wisconsin		
All species	33 *	17
Permanent residents	4	4
Short-distance migrants	14 *	5
Long-distance migrants	15	8
Vireos and warblers	8	5

* $P < 0.05$

(Table 4). Of these four, only the Rose-breasted Grosbeak was more prominent on control than treatment segments.

More species and short-distance migrants were observed first on treatment transects in Wisconsin, opposite of results from Michigan (Table 5). However, as in Michigan there were no differences in sequence of observations of permanent resident species between control and treatment transects (Table 5).

Breeding Bird Censuses

Michigan. Seventy-four species and 2267 individuals were observed on all control and treatment transects in Michigan during the June breeding bird census (Appendix 4a). Sixty-eight species and 1169 individuals were recorded on control and 60 species and 1098 individuals were observed on treatment transects (Appendix 4A, Table 6). The Ovenbird was the most abundant species on both control and treatment transects (Table 6). Based on ANOVA, more Nashville Warblers were observed on treatment than control transects but no other differences were detected (Table 6). Six of 30 non-parametric tests between species prominence values on control and treatment transects were significant with three species having higher values for control and three for treatment transects (Table 7).

Wisconsin. Seventy-two species and 2257 individuals were recorded on all control and treatment transects in Wisconsin during the June breeding bird census (Appendix 4b). Fifty-seven species and 1050 individuals were recorded on control and 66 species and 1207 individuals were observed on treatment transects (Appendix 4B, Table 6). The Ovenbird was recorded most often on both control and treatment transects (Table 6). Based on ANOVA, more individuals and Ovenbirds were observed on treatment than on control transects (Table 6). In addition, four species had higher prominence

Table 6. Mean observations in a 500 m segment and significance of one-way ANOVA between control (C) and treatment (T) segments for the June breeding bird period in Michigan and Wisconsin.

Parameter	Michigan		Wisconsin	
	T	C	T	C
Least Flycatcher ¹	0.7	1.7		
Hermit Thrush ²			1.0	0.7
Red-eyed Vireo	2.5	2.5	2.4	2.6
Nashville Warbler	3.4 *	1.6	3.1	2.6
Chestnut-sided Warbler	1.7	1.3	1.8	1.4
Black-throated ₂ Green Warbler ²	1.4	1.7	1.4	1.0
Ovenbird	4.4	5.0	4.4	4.8
Rose-breasted Grosbeak	0.8	1.4		
White-throated Sparrow	1.5	0.8	2.5	2.0
Individuals	27.5	29.2	30.2 *	26.3
Species	11.1	12.5	12.3	11.3

* $P < 0.05$

¹Log transformed in Michigan analysis

²Log transformed in Wisconsin analysis

Table 1. Species with significant differences during June 1986 between control and treatment transects (see Table 4).

Species	Michigan						Wisconsin					
	Transect		Individual		PV		Transect		Individual		PV	
	T	C	T	C	T	C	T	C	T	C	T	C
Buffed Grouse	7	1	8	1	3.3	0.2						
Eastern Wood-Pewee							2	8	2	10	0.4	4.5
Yellow-bellied Flycatcher	16	9	33	14	19.5	6.4						
Great Crested Flycatcher							2	11	3	15	0.7	7.9
Blue Jay	15	9	28	13	17.1	6.2						
Winter Wren	9	12	9	21	4.3	11.5						
Golden-crowned Kinglet							17	11	35	14	22.8	7.3
Veery							3	11	4	21	1.1	11.0
Northern Parula	4	10	8	18	2.5	9.0						
Yellow-rumped Warbler	33	3	19	3	10.8	0.8						
Common Yellow-throat	2	10	6	30	1.3	15						
Canada Warbler							6	11	9	23	3.5	12.1
Rose-breasted Grosbeak							7	14	8	24	3.3	14.2
Indigo Bunting							7	1	14	1	5.9	0.2
Chipping Sparrow							12	4	28	5	15.3	1.6
Song Sparrow	5	10	7	18	2.5	9.0						
Suway Sparrow							7	2	17	2	7.1	0.4
Red-winged Blackbird	2	11	2	34	0.4	17.8						
Brown-headed Cowbird	1	7	1	10	0.2	4.2						
Number of Species Tested	30						26					

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

values on control and four had higher values on treatment transects (Table 7).

Late-breeding Bird Censuses

Michigan. The number of birds observed declined from June to July in Michigan (Figure 4) when 75 species and 1716 individuals were recorded on all control and treatment transects (Appendix 4A). Sixty-three species and 978 individuals were observed on control transects and 59 species and 938 individuals were observed on treatment transects (Table 8). The Ovenbird was again the most common species on treatment transects, although the mean number of observations was less than in June (Table 8). The Red-eyed Vireo was observed most often on control transects but, in contrast to the Ovenbird, the number of observations increased from June to July on control transects. Two of 10 ANOVA tests indicated that more individuals of two species were observed on treatment than on control transects (Table 8). In contrast, three of 21 species tested had higher prominence values on control than treatment transects (Table 9).

Wisconsin. The number of individuals observed in Wisconsin also declined from June to July (Figure 4). Sixty-four species and 1666 individuals were observed on all control and treatment transects (Appendix 4b). Fifty species and 808 individuals were observed on control and 54 species and 858 individuals were counted on treatment transects (Appendix 4B, Table 8). The Red-eyed Vireo was the most common species on both control and treatment transects (Table 8). One notable change in the bird community was the large decrease in the number of Ovenbirds from May (Table 3) and June (Table 6) to July (Table 9). In July, only 33 and 15 individuals were observed on control and treatment transects, respectively (Table 9) and

Figure 4. Monthly means (\pm 95% confidence intervals) of number of individuals/500 m segment in Michigan (A) and Wisconsin (B) during 1986. Values for control and treatment transects are offset for clarity and do not indicate that control and treatment transects were sampled on different days.

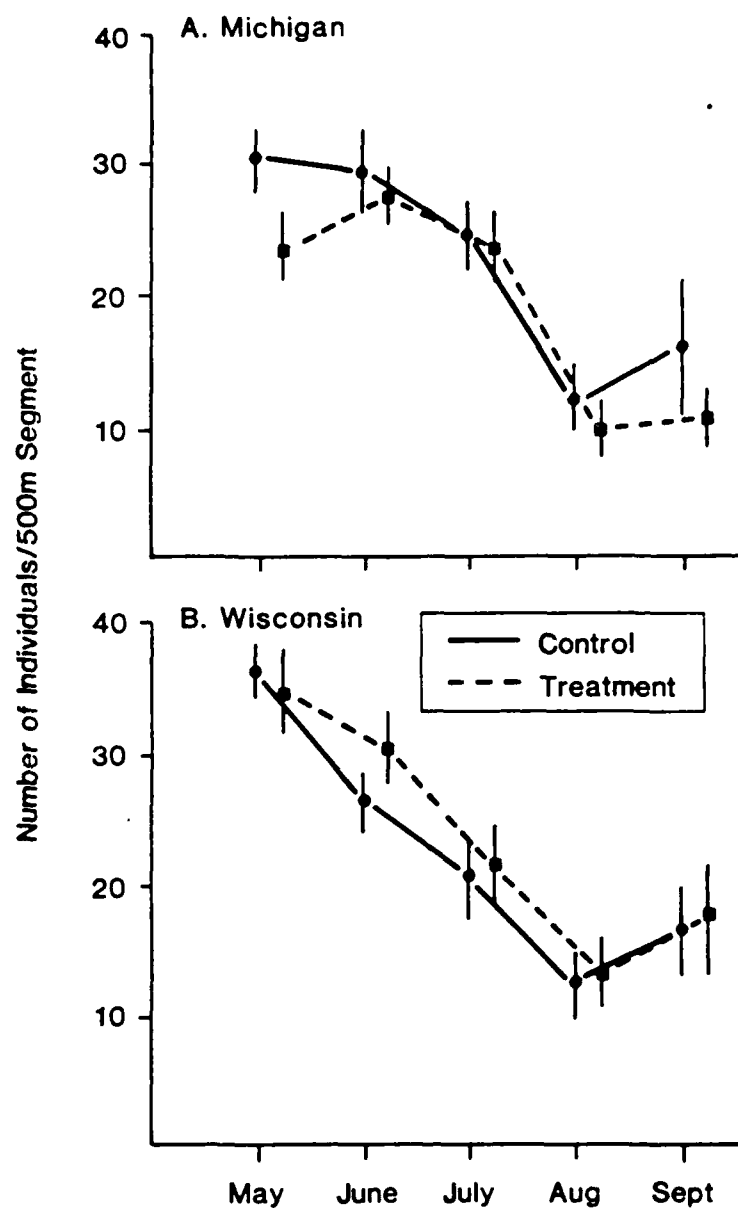


Table 8. Mean observations in a 500 m segment and significance of one-way ANOVA between control (C) and treatment (T) segments for the July late breeding bird period in Michigan and Wisconsin.

Parameter	Michigan		Wisconsin	
	T	C	T	C
Black-capped Chickadee	1.2	1.5	1.5	1.7
Golden-crowned Kinglet	1.2	0.6	1.1	0.6
Hermit Thrush	2.0 *	1.1	1.5	1.1
Red-eyed Vireo	1.9	2.9	3.0	3.2
Nashville Warbler ¹	2.0 **	0.7		
Black-throated ₁ Green Warbler ¹	1.0	1.4		
Ovenbird	2.7	2.7		
White-throated Sparrow ²	1.9	1.3	1.8	2.9
Individuals	23.5	24.5	21.5	20.2
Species	9.6	10.4	8.4	7.8

* $P < 0.05$; ** $P < 0.01$

¹Log transformed in Michigan analysis

²Log transformed in Wisconsin analysis

Table 3. Species with significant differences during July 1986 between control and treatment transects (see Table 4).

Species	Michigan						Wisconsin					
	Transect		Individual		PV		Transect		Individual		PV	
	T	C	T	C	T	C	T	C	T	C	T	C
Ruffed Grouse	2	7	2 ***	26	0.4 ***	10.9						
Downy Woodpecker	4	8	6 *	15	1.9	6.7						
Least Flycatcher	2	7	2 ***	17	0.4 **	7.1						
Blue Jay							10	13	15 **	33	7.5 **	21.7
Yellow-rumped Warbler							6	3	15 *	4	5.8	1.1
Ovenbird							12	16	15 **	33	8.2 *	20.9
Common Yellowthroat	3 *	11	8 **	26	2.2 **	13.6						
Swamp Sparrow							7	3	22 ***	3	9.2 **	0.8
Number of Species Tested						21						19

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

this difference was significant. Two other species showed significant differences between prominence values on control and treatment transects with one having a larger value on control and one a larger value on treatment transects (Table 9).

Early Fall Migration Bird Censuses

Michigan. The number of individuals and species observed continued to decline as the summer progressed (Figures 4 and 5). Sixty-one species but only 858 individuals were observed on both control and treatment transects during August (Appendix 4A). Forty-six species and 478 individuals were observed on control transects and 53 species and 380 individuals were counted on treatment transects (Appendix 4A, Table 10). Only one species, the Black-capped Chickadee occurred in the study areas at a density > 1 individual/segment (Table 10) and only one of 15 species tested, the Downy Woodpecker, showed a difference in prominence values between control and treatment transects (Table 11).

Wisconsin. Number of individuals observed in Wisconsin was also lowest during August (Figure 4). Forty-seven species and 999 individuals were counted on control and treatment transects (Appendix 4B). Thirty-eight species and 477 individuals were recorded on control and 40 species and 522 individuals were sighted on treatment transects (Appendix 4B, Table 10). The Black-capped Chickadee was the most common species, paralleling results from Michigan (Table 10). Two species had higher prominence values on treatment than control transects but no other comparisons were significant (Tables 10 and 11).

Figure 5. Monthly means (\pm 95% confidence intervals) of number of species/500 m segment in Michigan (A) and Wisconsin (B) during 1986 (see Figure 4).

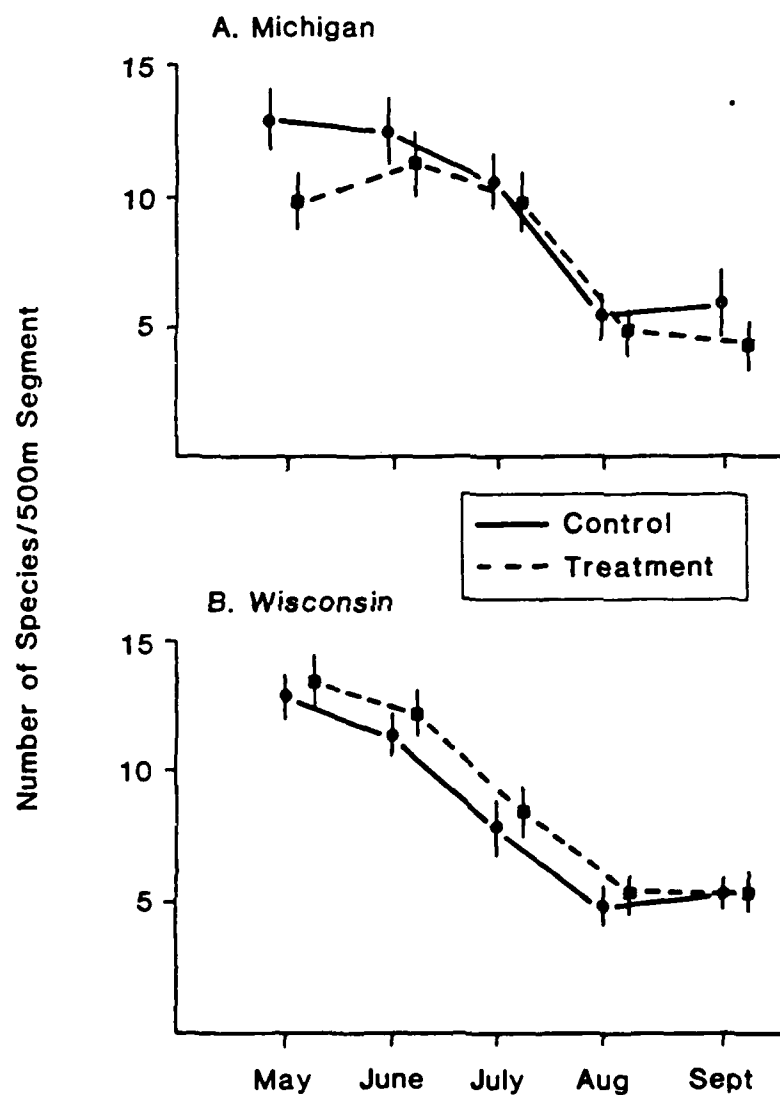


Table 10. Mean observations in a 500 m segment and significance of one-way ANOVA between control (C) and treatment (T) segments for the August early fall migration period in Michigan and Wisconsin.

Parameter	Michigan		Wisconsin	
	T	C	T	C
Black-capped Chickadee ²	1.1	2.1	1.6	2.3
Golden-crowned Kinglet			1.4	0.9
Ovenbird			1.1	0.9
White-throated Sparrow ²			0.6	1.1
Individuals	9.6	12.0	13.1	12.2
Species	4.6	5.2	5.3	4.8

²Log transformed in Wisconsin analysis

Table 11. Species showing significant differences during August 1986 between control and treatment transects (see Table

Species	Michigan						Wisconsin					
	Transect		Individual		PV		Transect		Individual		PV	
	T	C	T	C	T	C	T	C	T	C	T	C
Downy Woodpecker	5	11	5 ± 18		1.8 ±	9.4						
Hermit Thrush							12 ±	4	13 ±	4	7.1 ±	1.3
Nashville Warbler							11 ±	2	21 ±	5	11.0 ±	1.1
Number of Species Tested					15						12	

± P < 0.05; ±± P < 0.01

Fall Migration Bird Censuses

Michigan. The number of individuals observed increased from August to September (Figure 4) but species richness (Figure 5) was the lowest of all seasons during this period (Appendix 4A). Fifty-five species and 1029 individuals were counted on all control and treatment transects with 627 individuals and 48 species recorded on control and 402 individuals and 36 species recorded on treatment transects (Appendix 4A, Table 12). As in August, the Black-capped Chickadee was the most common species on both control and treatment transects (Table 12). Several differences were detected between control and treatment transects and similar to the spring migration period, all but one indicated higher number of individuals, species, or prominence values on control versus treatment transects (Tables 12 and 13).

Wisconsin. The number of individuals observed increased in Wisconsin between August and September but the number of species observed was almost equal (47 and 48 in August and September, respectively) (Figures 4 and 5, Appendix 4B). Thirty-one species and 682 individuals were recorded on control and 39 species and 644 individuals were counted on treatment transects (Appendix 4B, Table 12). The Black-capped Chickadee was the most commonly observed species in control areas while the Yellow-rumped Warbler was the species most often observed in treatment areas (Table 12). One species, the Ruffed Grouse had a higher prominence value on control than on treatment transects (Table 13).

Seasonal Bird Population Trends

Michigan. The number of species and individuals observed on Michigan control transects were highest in May, declined throughout August, and then increased during September (Figures 4 and 5). In contrast, the number of

Table 12. Mean observations in a 500 m segment and significance of one-way ANOVA between control (C) and treatment (T) segments for the September late fall migration period in Michigan and Wisconsin.

Parameter	Michigan		Wisconsin	
	T	C	T	C
Black-capped Chickadee ¹	1.7	3.1	3.4	3.3
Red-breasted Nuthatch			1.6	1.4
Golden-crowned Kinglet	1.4	1.4		
Yellow-rumped Warbler ²			4.9	2.6
White-throated Sparrow			1.1	1.8
Individuals ¹	10.1 *	15.7	17.1	16.0
Species ¹	4.0 *	5.6	5.3	5.3

* $P < 0.05$

¹Log transformed in Michigan analysis

²Log transformed in Wisconsin analysis

Table 13. Species showing significant differences during September 1986 between control and treatment transects (see Table 4).

Species	Michigan						Wisconsin					
	Transect		Individual		PV		Transect		Individual		PV	
	T	C	T	C	T	C	T	C	T	C	T	C
Ruffed Grouse							5	8	6 **	21	2.1 *	9.4
American Crow							6 *	0	8 **	0	3.1	0
Blue Jay	14	19	19 *	37	11.5 *	25.5						
Brown Creeper	4	6	4 **	16	1.3	6.2						
Ruby-crowned Kinglet							10	6	18 *	8	9.0	3.1
Yellow-rumped Warbler	6	9	17 *	34	6.6 *	16.1						
American Redstart	0 *	6	0 ***	19	0 *	7.4						
Ovenbird	6	10	8 *	21	3.1 *	10.5						
White-throated Sparrow	12 *	4	36 ***	10	19.7 ***	3.2						
Number of Species Tested						15						10

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

individuals and species observed on treatment transects increased from May to June and then decreased steadily throughout the remaining census periods (Figures 4 and 5). Numbers of individuals and species observed were higher on control than on treatment transects in each census period and differences were detected in both the spring and late-migration periods for species and individuals (Table 14, Figures 4 and 5).

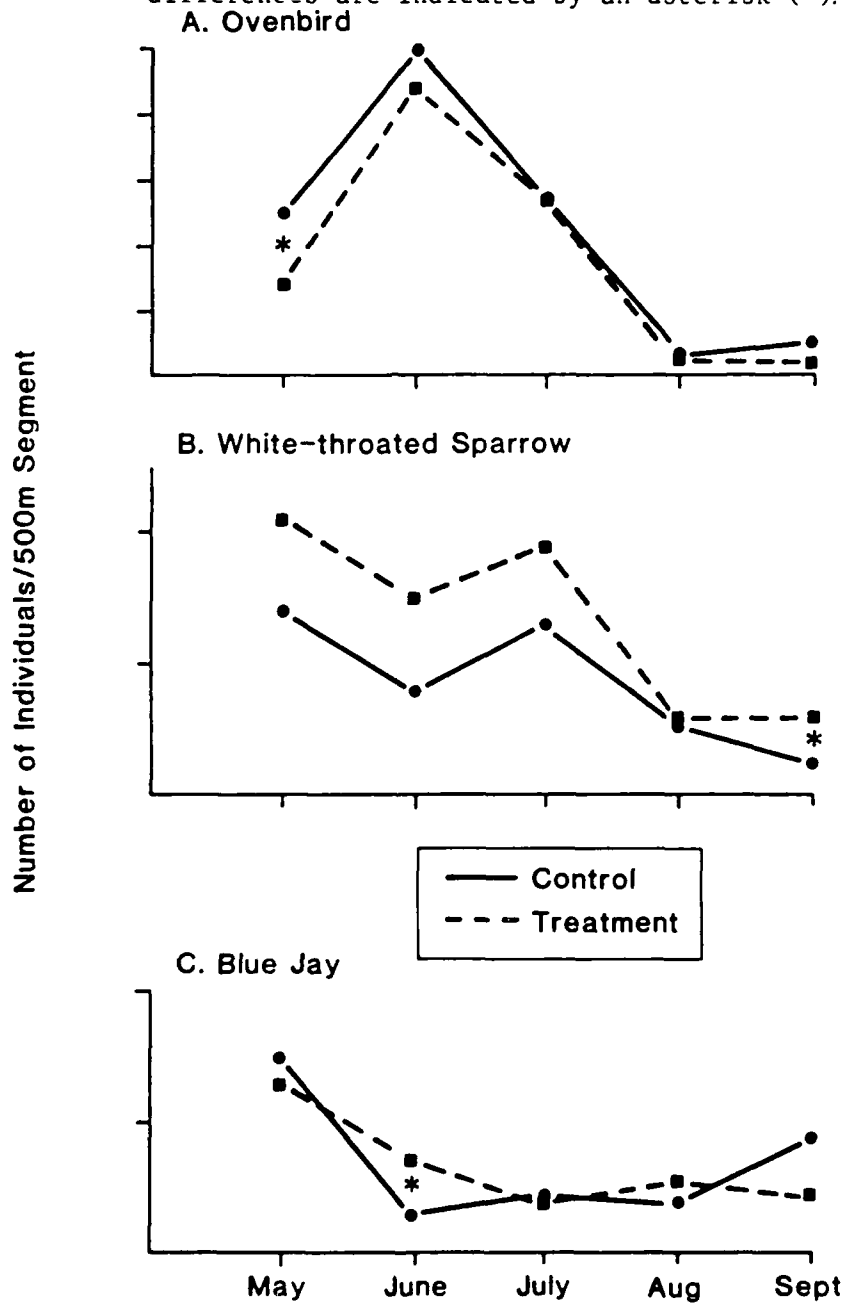
Two summer resident species, the Nashville Warbler and Ovenbird, were the most commonly observed species on both control and treatment transects throughout the spring, breeding, and late-breeding census periods (Tables 4, 6, and 8). However, during the early and late-migration periods, a permanent resident species, the Black-capped Chickadee was most abundant (Tables 10 and 12). We summarized seasonal trends of species that were tested for differences in number of observations (ANOVA) or prominence values (G-test or Fisher Exact) between control and treatment transects for at least two census periods (Table 14) and classified them into three types of patterns: (1) species that had consistently higher numbers on control transects, (2) species with consistently higher numbers on treatment transects, and (3) species that showed no consistent pattern of abundance between control and treatment transects (Figure 6). Of the 17 species examined, seven species were observed consistently more often on control than treatment transects, two species more often on the treatment transects, and the remaining eight species showed no consistent trend among seasons (Table 14).

Wisconsin. The number of individuals and species observed on control and treatment transects in Wisconsin followed seasonal trends similar to Michigan (Figures 4 and 5). Most species and individuals were counted during the spring migration period and then the number of individuals

Table 14. Summary of seasonal trends for species with a significant difference in abundance between control and treatment transects (based on G-tests of prominence values or ANOVA tests) in at least one month in 1986. Abundance is indicated as being greater on control (C) or treatment (T) transects; E indicates equal numbers on control and treatment. A significant monthly difference is indicated with an asterisk (*).

Parameter	Michigan					Wisconsin				
	M	J	J	A	S	M	J	J	A	S
Ruffed Grouse	T	T	C*		C	E				C*
Yellow-bellied Sapsucker	C*	T	C	C	C					
Downy Woodpecker	C	T	C	C*	C					
Least Flycatcher	C	C	C*							
Blue Jay	C	T*	C	T	C*	T	T	C*	T	C
Winter Wren	C*	C	T							
Golden-crowned Kinglet						T	T*	T	T	C
Hermit Thrush	C	C	T*		C	C	T	T	T*	T
Nashville Warbler	T	T*	T*			E	T	T	T*	
Northern Parula						C*	C			
Yellow-rumped Warbler T		T*	C		C*					
Black-and-white Warbler	C*	C				C*	E			
Ovenbird	C*	C	E	C	C*	C	C	C*	T	
Common Yellowthroat		C*	C*							
Canada Warbler							C*	E		
Rose-breasted Grosbeak	C*	C				C*	C*			
Chipping Sparrow	C*	E	T			T	T*			
Song Sparrow						T*	T	T		
Swamp Sparrow							T*	T*		
White-throated Sparrow	T	T	T	T	T*					
Red-winged Blackbird	C*	C*								
Brown-headed Cowbird	C*	C*								
Individuals	C*	C	C	C	C*	C	T*	T	T	T
Species	C*	C	C	C	C*	T	T	T	T	E

Figure 6. Examples of species that were consistently more abundant on control (A), treatment (B) transects, or that showed no consistent pattern among seasons (C). Significant monthly differences are indicated by an asterisk (*).



observed declined steadily throughout the breeding, late-breeding, and early-migration censuses until a slight increase in numbers observed occurred during the late-migration period (Figures 4 and 5). Only one significant difference was detected between control and treatment transects for these population parameters in any season and this was more individuals observed on treatment than control transects during the breeding season (Table 14).

Seasonal trends for individual species are summarized in Table 14 for those species that were tested in more than one season. Patterns for species specific differences were categorized as they were in Michigan (see Figure 6). Five species were observed consistently more often on control than on treatment transects throughout the seasons, four species were observed consistently more often on treatment transects, and four species showed no consistent seasonal pattern (Table 14).

Annual Bird Population Trends

Michigan. More species and individuals were observed in both control and treatment transects in 1985 compared with the 1986 breeding season (Table 15). Seven species were observed less frequently in both control and treatment transects in 1986 as compared with 1985 (Table 15). The number of individuals observed for three species remained stable between 1985 and 1986 (Table 15). We detected several differences in prominence values between 1985 and 1986 (Table 16), but only one species, the Mourning Warbler, followed the pattern that was detected with the 2-way ANOVA (e.g. prominence values decreased on both control and treatment transects). In contrast, prominence values for Golden-crowned Kinglet were higher on both control and treatment transects in 1986 than in 1985. Five species showed an increase in prominence values on control transects but a decrease on

Table 15. Mean observations in a 500 m segment and significance of two-way ANOVA between control (C) and treatment (T) segments and between years (1985 and 1986) for the June breeding bird period in Michigan and Wisconsin.

Parameter	Michigan				Wisconsin			
	1985		1986		1985		1986	
	T	C	T	C	T	C	T	C
Yellow-bellied Flycatcher ²					0.6 *	1.7	0.8	I 0.6
Least Flycatcher ^{1,2}	0.9	1.2	0.7	1.7	0.3 *	1.6 *	0.5	0.7
Hermit Thrush ¹	1.0	1.2 **	0.3	0.4	0.8	0.8	1.0	0.7
Red-eyed Vireo	4.7	3.6 **	2.5	2.5	4.6	4.5 *	2.4	2.6
Nashville Warbler ¹	5.7 **	2.4 **	3.4 **	1.6	4.3	3.2	3.1	2.6
Chestnut-sided Warbler ¹	4.1 *	1.5 *	1.7	1.3	2.0 *	1.0	1.8	1.4
Black-throated Green Warbler ²	1.8	2.6 *	1.4	1.7	2.5	3.0 **	1.4	1.0
Ovenbird	6.5	6.1 **	4.4	5.0	7.0	6.0 **	4.4	4.8
Mourning Warbler ¹	1.5 *	0.5 *	0.5	0.5				
Common Yellowthroat ²					1.1	0.6	0.6	0.3
Rose-breasted Grosbeak	0.8 *	1.3	0.8	1.4				
White-throated Sparrow	1.9 **	0.9	1.5	0.8	1.3	0.9 **	2.5	2.0
Individuals	40.9 **	33.2 *	27.5	29.2	38.8 **	33.9 **	30.2 *	26.3
Species	14.3	14.0 **	11.1	12.5	15.0 *	13.1 **	12.3	11.3

* $P < 0.05$; ** $P < 0.01$

¹ Log transformed in Michigan

² Log transformed in Wisconsin

I Significant interaction

Table 16. Species showing significant annual differences between 1985 and 1986 during the June breeding bird censuses (see Table 7).

Species	Michigan								Wisconsin															
	Transect				Individual				PV				Transect				Individual				PV			
	85	86	85	86	85	86	85	86	85	86	85	86	85	86	85	86	85	86	85	86				
Eastern Wood-Pewee	C	7	9	8	11	3.4	5.2			9	8	12	16	5.7	4.5									
					†		†						†		†									
	T	13	5	18	5	10.3	1.8			8	2	16	2	7.2	6.4									
Yellow-bellied Flycatcher	C	6	9	6	14	2.3	6.6																	
					†																			
	T	14	14	44	33	26.0	19.5																	
Blue Jay	C	23	9	32	13	24.3	6.2																	
					††		††																	
	T	19	15	21	28	14.5	17.1																	
Winter Wren	C									15	14	32	23	19.6	13.6									
												†††		†††										
	T									6	17	8	30	3.1	19.6									
Golden-crowned Kinglet	C	3	8	3	19	0.8	8.5																	
					††		†																	
	T	12	12	26	26	13.6	14.2																	
American Robin	C	17	20	21	30	13.7	21.2																	
					†		†																	
	T	19	14	41	23	28.3	13.6																	
Black-and-white Warbler	C	25	16	43	25	34.0	15.8																	
					†		†																	
	T	9	13	14	20	6.6	11.4																	
Mourning Warbler	C	10	9	19	17	9.5	8.1																	
					††		†																	
	T	18	9	60	18	40.2	8.5																	

Table 16 continued

Common	C	8	10	22	30	9.8	15.0
Yellowthroat				*		*	
	T	7	2	14	6	5.9	1.3
Rose-breasted	C					8	14
Grosbeak						14	24
						*	
	T					10	7
						16	8
						8.0	3.3
Chipping	C	3	10	4	13	1.1	6.5
Sparrow				*		*	
	T	9	8	18	13	8.5	5.8

* = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$

treatment transects from 1985 to 1986 (Table 16). Two species (Black-and-white Warbler and Blue Jay) showed a reverse pattern (Table 16).

Wisconsin. The 2-way ANOVA between the number of individuals observed in Wisconsin in 1985 and 1986 showed a pattern similar to that in Michigan. Most population parameters tested indicated that more individuals were observed on both control and treatment transects in 1985 than during the 1986 breeding season (Table 15). An exception to this pattern was the White-throated Sparrow which increased on both control and treatment transects from 1985 to 1986 (Table 15). In addition to the differences detected with the 2-way ANOVA, three species tested with non-parametric tests showed significant changes between the 1985 and 1986 breeding seasons (Table 16). Two species increased on control transects but decreased on treatment transects between 1985 and 1986 and one species showed the opposite pattern (Table 16).

Edge Effect of ROW on Bird Populations

Twenty-nine differences detected in 1985 and 1986 indicated that more individuals or higher species prominence values were observed on treatment than control transects. One possible explanation for more birds on treatment transects is that the ROW edge attracts birds. Although our transect was designed to reduce edge effect (we do not census the ROW or the 25 m adjacent to it) it is possible that effect of the ROW edge penetrates deeper into the forest for some species than for others. In 12 of 84 comparisons, the number of birds observed on the right versus left side (for control transects) or adjacent versus opposite the ROW (for treatment transects) from the transect center line were different (Table 17, Figures 7 and 8). Six differences were detected on control transects and six on

Figure 7. Distribution of bird observations in 25 m belts to either side of transect center lines (dashed lines) in Wisconsin. For treatment transects, records to the left of the center line are closer to the antenna corridor.

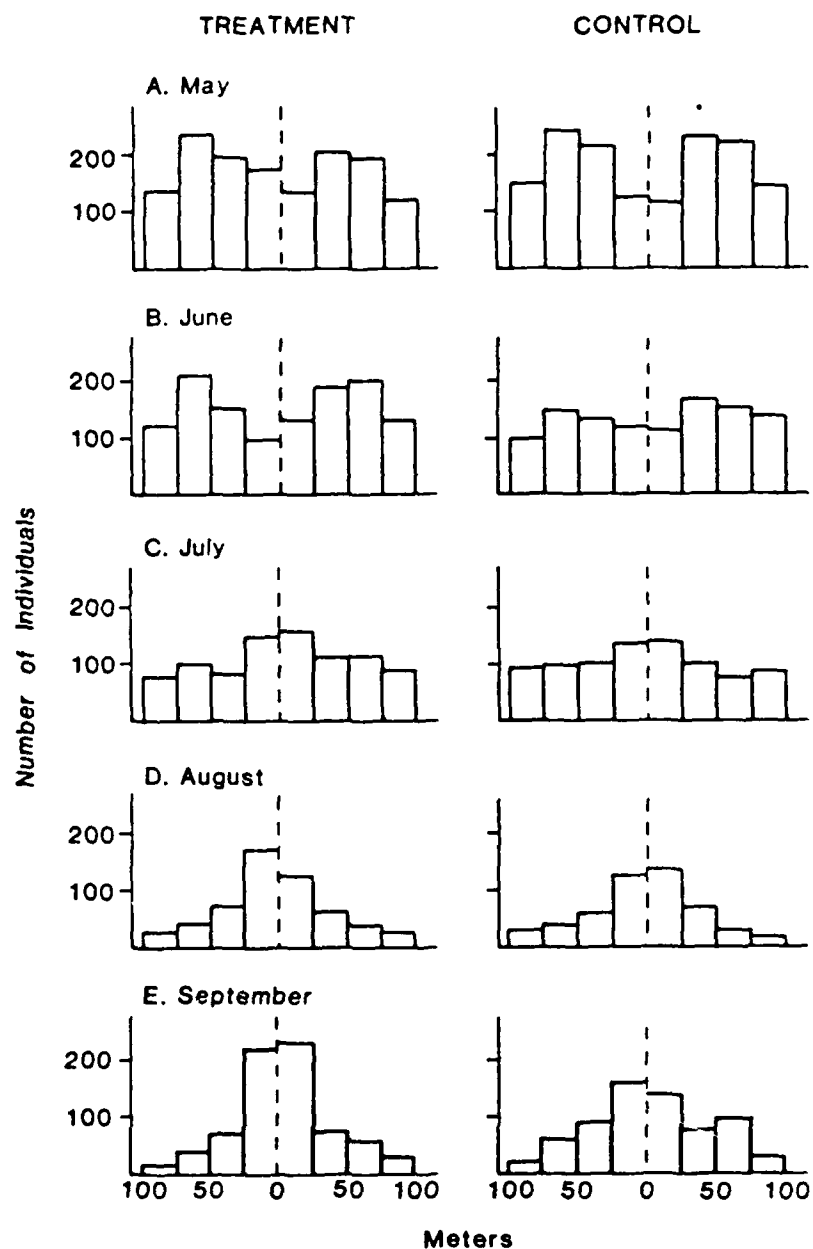


Figure 8. Distribution of bird observations in 25 m belts to either side of transect center lines (dashed lines) in Michigan. For treatment transects, records to the left of the center line are closer to the antenna corridor.

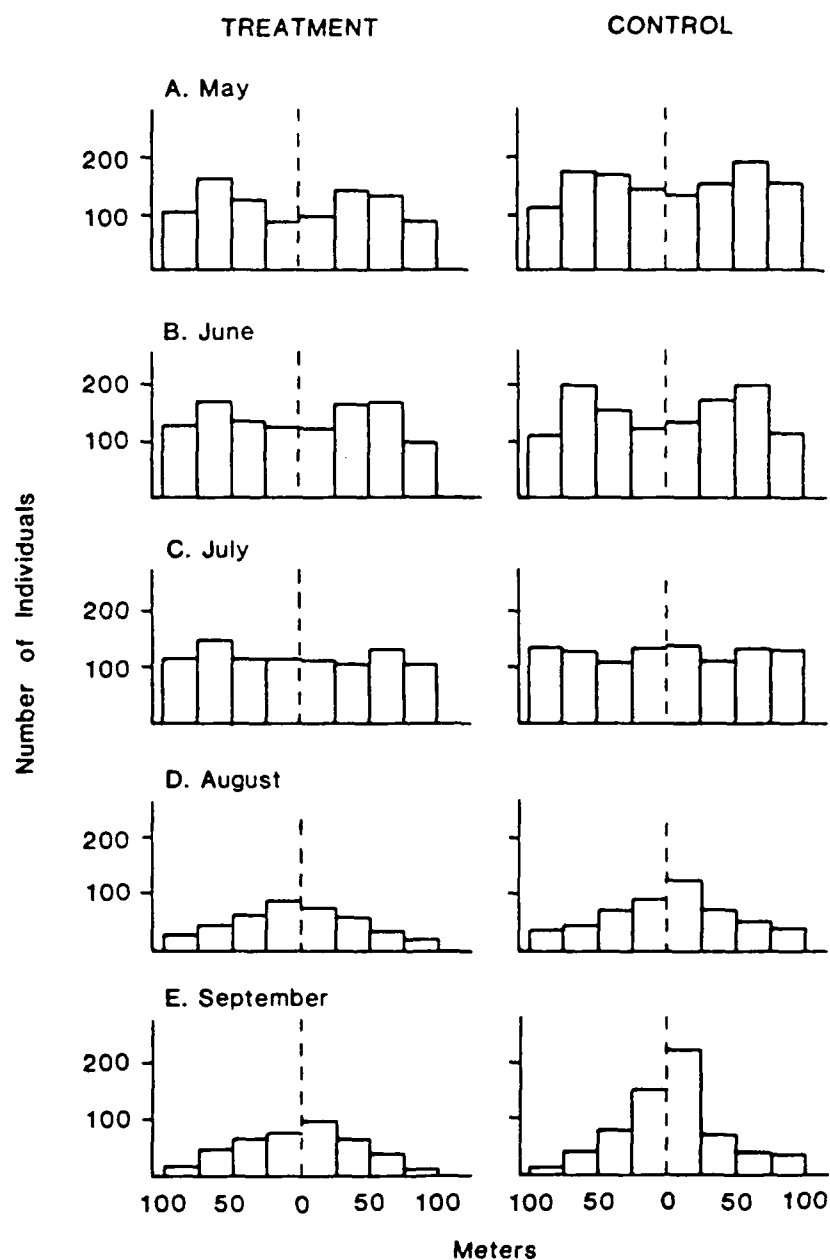


Table 17. Number of birds observed on right or left side of transects for controls or adjacent to the ROW or opposite for treatment transects for bird population parameters in Michigan and Wisconsin in 1985 and 1986. Bird distribution was tested with a chi-square or G-test for those parameters that indicated significantly more ($P < 0.05$) individuals on treatment than control transects. Only significant tests are shown.

Parameter	State	Season	Year	Treatment		Control	
				Opposite	Adjacent	Right	Left
Individuals	MI	June	85	828	808	706 *	623
	MI	May	86	466	483	616 *	594
	MI	Sept	86	201	201	351 **	276
	WI	June	86	639 *	568	562 *	488
Yellow-bellied Flycatcher	MI	June	86	8 **	25	11 *	3
Hermit Thrush	MI	July	86	38	40	15 *	29
Nashville Warbler	MI	June	86	50 **	86	32	33
	WI	Aug	86	6 *	15	3	2
Chestnut-sided Warbler	WI	June	85	31 *	49	24	15
Indigo Bunting	WI	June	86	1 ***	13	1	0

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

treatment transects. It is difficult to interpret these results. If birds are distributed randomly, we would expect that no differences should be detected on control transects. If there is an edge effect, then there should be more individuals detected adjacent to the antenna than away from the transect center line. If the ROW edge attracts a particular species we would expect a pattern of more observations on the side adjacent to the ROW in both states and in all seasons. The Nashville Warbler is the only species that occurred adjacent to the ROW more often than opposite to it in more than one test (Table 17), indicating a possible attraction to the ROW edge for this species. Other species that were more abundant on the ROW side as compared with the opposite side in one test included the Chestnut-sided Warbler, Yellow-bellied Flycatcher, and Indigo Bunting (Table 17). Of these species, the Indigo Bunting was the only species that showed a strong trend to occur in the 75-100 m (distance from center line) belt adjacent to the ROW.

Observer Variation

Only one difference was detected in birds counted in the observer variability test (Table 18). In these censuses of eight segments, observer one recorded more Ovenbirds than observer two. No differences were detected between observers in 12 other community or species-specific tests (Table 18).

Wisconsin Vegetation

Vegetation sampling was completed on more than half of the control and treatment transects in Wisconsin in late-June through early-August 1986. The remaining transects will be measured in the same time period in 1987. Twenty-five tree, 47 shrub, and 73 forb species were identified along the transects measured this year (Appendix 5). Data analyses will be initiated

Table 18. Mean number/500 m segment for bird parameters tested with a paired t-test between two observers from simultaneous census of 8 segments in Wisconsin during June of 1986.

Parameter	Observer	
	One	Two
Yellow-bellied Flycatcher	0.8	1.1
Least Flycatcher	1.0	2.3
Winter Wren	1.1	1.0
Hermit Thrush	0.9	0.6
Red-eyed Vireo	3.1	3.6
Nashville Warbler	2.9	2.9
Chestnut-sided Warbler	1.3	1.4
Black-throated Green Warbler	0.9	1.4
Ovenbird	7.1	* 5.4
Rose-breasted Grosbeak	0.9	0.9
White-throated Sparrow	3.9	3.8
Individuals	35.1	36.5
Species	12.0	12.4

* $P < 0.05$

over the winter and results will be reported in future reports after all analyses are completed.

Michigan Vegetation

Vegetation along control and treatment transects were different in percentage of points identified for three of 19 habitat types (Table 19). Control transects had more maple and cedar habitats, while treatment transects had more lowland conifer habitat (Table 19). If categories are combined on a more general scale to compare percent of lowland and upland forests and lowland and upland shrub habitats, control and treatment transects within these broader categories are relatively similar. For example, lowland forests comprised 20% of control and 26% of treatments, upland forests comprised 43 and 41% of control and treatments, respectively, lowland shrubs were present on 8% of both control and treatments, and upland shrubs were present on 7 and 12% of control and treatment transects, respectively. From an ornithological perspective, it is important to identify the habitat types that were not present on either control or treatment transects. These included recently logged habitats in treatment areas but not in control areas, and pond and cattail habitats in control but not in treatment areas (Table 19).

Non-parametric Tests

Twenty-seven of 135 G-tests using frequency of species occurrence (used in 1985 but see Appendix 6) on control versus treatment transects indicated a significant difference (Tables 4, 7, 9, 11, and 13). In contrast, 86 of 135 G-tests using the number of individuals observed on control versus treatment transects and 68 of 135 G-tests using the prominence values were significant. In general, when the test between

Table 19. Percentage of points identified for each habitat type within Michigan control and treatment study areas (N = 840 in control and treatment). See Appendix 2 for a description of the habitat types.

Habitat Type	Control		Treatment
Upland conifer	1		6
Lowland conifer	7	**	21
Upland deciduous	7		14
Maple	12	*	4
Lowland deciduous	2		< 1
Upland mixed	23		17
Lowland mixed	10		4
Cedar	11	*	2
Wet shrub	2		2
Tree shrub	3		6
New cut	0		3
Young cut	1		4
Young mix	3		< 1
Short aspen	8		10
Short mix	5		2
Open	3		5
Sedge	1		< 1
Pond	1		0
Cattail	< 1		0

* $P < 0.05$; ** $P < 0.01$

transect frequency was significant, so was the test between prominence values and number of individuals. The increase in the number of significant tests from frequency to individuals is related to the magnitude of the values. The highest absolute values were obtained for number of individuals and lowest absolute values were obtained for test of frequency. Each test has merit and will be evaluated during the course of this study.

Expected and Observed Statistical Significance

A total of 589 statistical tests were computed for the 1985 and 1986 data presented and 231 of these indicated a significant difference between control and treatment transects (Table 20). We calculated the number of tests that would be expected to be different based on chance and compared this number to differences that we observed for each type of test and for the total number of tests. These analyses indicated that more G-tests and ANOVA's between control and treatment transects in both 1985 and 1986 showed differences more often than expected for all probability levels (Table 20). The total number of observed differences was higher than the number of expected differences at each probability level (Table 20) but this was largely due to the high number of non-parametric tests that were significant between control and treatment transects.

DISCUSSION

Annual Changes In Number Of Observations

Comparisons of the number of birds observed were based on data collected in June, the only month sampled in both 1985 and 1986. Total number of bird observations and species richness were lower in 1986 than in 1985 on both control and treatment transects and in both states. This suggests widespread declines in abundances of many species. Many changes in abundance of individual species involved differences of few individuals

Table 20. Number of statistical tests computed and observed (obs) versus expected (exp) number of significant differences at three probability levels for each type of test.

Statistical Test	# Tested	P<0.05		P<0.01		P<0.001	
		Obs	Exp	Obs	Exp	Obs	Exp
ANOVA (85 & 86)	103	27 ***	5.2	14 ***	1.0		
G-test 86	196	113 ***	9.8	57 ***	2.0	27 ***	0.2
85	62	44 ***	3.1	23 ***	0.6	11 ***	0.1
ANOVA, G-test (between years)	144	23 **	7.4	6	1.5	2	0.2
Chi-square (right vs. left)	49	12 *	2.5	4	0.5	1	0.05
G-test (arrival time)	10	4	0.5				
Paired T-test (between observers)	13	1	0.7				
G-test (Habitat MI)	12	3	0.6	1	0.1		

* P < 0.05; ** P < 0.01; *** P < 0.001

(38 of 83 species showing a change in Wisconsin; 53 of 88 species in Michigan) and the biological significance of such change is probably low. In many cases, changes (increases or decreases) may not be statistically significant at the species level. However, we still can examine general trends in the numbers of species that increased or decreased. Among species that changed in abundance by at least six individuals, 32 decreased and 13 increased in Wisconsin from 1985 to 1986, while 20 decreased and 15 increased in Michigan. These results illustrate two points. First, because species differ in many life history characteristics (e.g., preferred food, reproductive output, population density), changes in abundance from one year to the next vary both in magnitude and direction when different species are considered. Second, these results suggest that much of the difference in number of observations between 1985 and 1986 largely was due to decreases for a few species.

Using a change in abundance of at least 25 individuals as an arbitrary criterion for a "large" change, 11 species in Wisconsin declined in abundance by a combined total of 713 individuals. Species showing the largest declines were Red-eyed Vireo (166 fewer individuals observed; statistically significant), Ovenbird (150; statistically significant), Black-throated Green Warbler (125; statistically significant), and Nashville warbler (70). In contrast, only three species increased in abundance by at least 25 individuals: White-throated Sparrow (92; statistically significant), Golden-crowned Kinglet (42), and Blackburnian Warbler (30). In Michigan, we observed 748 fewer individuals for nine species, including Red-eyed Vireo (132; statistically significant), Ovenbird (125; statistically significant), Nashville Warbler (123; statistically significant), and Chestnut-sided Warbler (104; statistically significant). No

species in Michigan increased in abundance by more than 25 individuals. Five species declined considerably in both states which suggests a region-wide pattern.

Many factors may cause bird abundance to decline, including weather (both directly and indirectly through effects on food supplies), habitat destruction, nest parasitism, predation, and disease (e.g., Jackson 1977; Graber and Graber 1979; Whitcomb et al. 1981; Loiselle and Hoppes 1983; Wilcove 1985). Chance events (e.g., local effects of predation, resource distribution, weather, regional population density and habitat selection) also may produce apparent declines in populations, particularly over local areas. Although two segments were altered slightly by logging, there were no large scale habitat modifications that would have caused widespread declines in bird abundance. Similarly, although loss of wintering habitat has been postulated as a factor contributing to long-term declines of migratory birds (Briggs and Criswell 1979; Ambuel and Temple 1982; Serrao 1985), it is not likely that such an effect would be evident over one winter. Disease can have a widespread effect on animal populations (Dobson and May 1986).

Predation and parasitism are most likely to affect birds within local areas (e.g., Wilcove 1985) and thus do not seem likely causes of widespread declines in abundance. Predation and nest parasitism frequently are more severe near forest edges than in forest interiors (Gates and Gysel 1978; Chasko and Gates 1982; Brittingham and Temple 1983). The presence of the ROW near treatment transects may result in higher predation/parasitism pressure here than on control transects, leading to declines in abundance of some species. However, abundance declined on both types of transect, suggesting that nest predation and parasitism were not substantially higher on treatment transects.

By contrast, weather patterns may affect large areas (Graber and Graber 1977) and weather related factors appear most likely to have produced the declines in abundance observed in this study. Weather during spring and early summer of 1986 was unusual in several respects; Michigan sites were drier than normal and Wisconsin sites were wetter than normal. Also, there was an unusually cold period early in the breeding season in 1986 that resulted in the almost complete loss of Tree Swallow young in Michigan (P. Lederle, personal communication to J. Hanowski). This loss was not followed by many renesting attempts, indicating that conditions for nesting (i.e., food levels) remained poor. As a consequence, many individuals may have left the area. Although no similar data regarding loss of broods are available from northern Wisconsin, a similar, although perhaps less severe decrease in nesting success may have occurred there as well. Such a depression in breeding, coupled with early departure from study areas could have produced lower abundance in 1986 relative to 1985. Such an effect during the breeding season could then influence population levels during later months, especially July and August.

There was a decline in number of individuals observed as the summer progressed in both states. However, these apparent declines may have been an artifact of bird behavior. As the breeding season progresses, singing activity drops precipitously. Because a majority of our bird observations are based on sound, the number recorded will decrease even without an actual drop in bird numbers. As summer progressed, bird observations were increasingly concentrated near transect center lines (Figures 7 and 8) which supports the possibility that observations declined at least partially due to changes in bird behavior. Data from 1987 may provide a basis for comparing the relative importance of behavioral changes versus

true population declines in producing seasonal changes in bird abundance. Similarly, data from subsequent breeding seasons will permit more adequate assessment of events that lead to observed annual changes in bird abundances.

Abundance On Control And Treatment Transects

Although overall abundance and abundance of several species were lower in 1986 than in 1985, such changes should not affect distribution patterns between control and treatment transects. The antenna was not operating in Michigan and observed differences in bird abundances between control and treatment transects must therefore be caused by some factor other than the EM fields produced by the antenna. One possible factor would be inherent habitat differences between control and treatment transects. If habitat differences are a primary factor, we expect patterns observed in 1985 to hold in 1986 as well. Alternatively, a variety of stochastic factors might produce apparent differences. Lack of a consistent pattern would suggest that chance events were important determinants of species distribution patterns.

The antenna has been operating in Wisconsin and thus it is difficult to separate effects of the antenna from other potential factors. However, if patterns in 1985 repeated in 1986, it is likely that some factor, whether it be habitat differences or the ELF antenna, was influencing bird distribution patterns in a similar fashion in both years.

Results from Michigan suggest that inherent habitat differences between control and treatment transects are not responsible for differences in bird distribution patterns. Exceptions are those species with specific habitat requirements that are unevenly distributed between control and treatment transects. Total abundance and species richness were higher

overall on treatment transects in 1985 but on controls in 1986. Among individual species, many showed a similar pattern of abundance on control and treatment transects between years, while many others did not. Moreover, only one abundant (at least one individual/segment) species, the Nashville Warbler, showed a consistent, significant difference between years. Analyses of prominence value data indicated that seven species showed a significant difference in abundance between control and treatment transects in 1985 and six in 1986. However, only two species (Yellow-bellied Flycatcher and Yellow-rumped Warbler) showed a consistent significant difference (more abundant on treatment transects) between years.

Results from Wisconsin indicate higher consistency between years with respect to total abundance and species richness; totals were higher on treatment transects in both years. However, many species showed reversed relative abundances between years on control and treatment transects and no species showed a consistent, significant difference between control and treatment transects in both years. Nine species showed a significant difference in prominence values between control and treatment transects in 1985 and eight in 1986. Of these, four species showed a similar pattern between years, with two more abundant on control transects and two on treatments.

Overall, results from Michigan show little consistency between years, suggesting no single factor currently distinguishes control and treatment transects. The next several years will provide crucial data regarding potential effects of the ELF antenna. Between year patterns in Wisconsin were somewhat more consistent, indicating that a similar factor or factors were operating in both years in that state. Again, several more years of data will allow more adequate determination of the consistency of these patterns.

Seasonal Bird Abundance Patterns

The preceding discussion focused on annual differences in the breeding season (June), although possible causes for the apparent decrease in abundance in bird numbers over the course of the summer also were discussed. Here we briefly examine seasonal patterns, focusing on consistency in differences between control and treatment transects among different census periods. Once again, a consistent pattern would be evidence that some factor (e.g., habitat) was operating to produce observed differences, whereas inconsistent patterns (i.e., between season shifts in relative abundance on control and treatment transects) would indicate that chance events might be more important in causing these differences.

Looking first at community level parameters, total abundance and species richness in Michigan were consistently higher on control than on treatment transects. Differences were significant, however, only during migration (spring and late-fall) when many birds are moving through the region. In contrast, abundance and species richness were higher in most seasons on treatment than on control transects in Wisconsin. The exceptions were that total abundance was greater on control transects in spring, but not significantly so, while in fall, species richness was similar on both transect types.

Individual species differed in the consistency of their abundance patterns between control and treatment transects among seasons. In Michigan, nine species showed a consistent pattern among seasons (includes any species recorded in at least two seasons and showing a significant difference between control and treatment transects in at least one season), whereas eight species showed at least one switch in relative abundance between control and treatment transects. Among species that were tested in

four or five seasons, only two showed the same pattern in each season, whereas six showed a switch. In Wisconsin, where, if the ELF antenna is affecting bird distribution patterns, we might expect greater consistency, twice as many species (9) showed a consistent pattern as showed a switch (4). However, among species tested in four or five seasons, only one showed a consistent pattern and four switched.

Because we do not yet have data over all seasons for more than one year, we are not able to evaluate seasonal patterns in species observed in 1986 for consistency between years. Such analysis will be included in future reports.

Edge Effect

The presence of the ELF antenna ROW is a potential source of variability in bird communities between control (no ROW) and treatment areas. Vegetation changes associated with clearing of the ROW attracts a different bird community than what is present in adjacent interior habitats and variety and density of organisms tends to increase at the border between different plant communities (Odum 1971). One possible means to control for difference in edge between control and treatment areas would have been to create sham ROW's next to control transects. However, because of the cost and logistics of clearing almost 50 miles of ROW, this design was not feasible. Our design, of placing treatment transects 125 m from the ROW edge and not including the ROW and the first 25 m next to the edge, was chosen in an attempt to eliminate vegetation differences and edge effect variability from the study design.

We examined our data to determine whether the ROW and edge affected total number of individuals observed and number of individuals observed for a particular species. We concentrated our analyses on community parameters

that indicated a significantly higher number of individuals on treatment transects. We assumed that if the ROW edge attracts birds, higher numbers would be observed in treatment than in control areas. In treatment areas, more individuals should be observed on the side adjacent to the antenna than opposite the transect center line. In addition, if birds are distributed randomly, we would expect that there would be no differences in bird distribution in control areas (e.g., equal numbers on right and left side of transect center)

Forty-nine parameters were tested and 12 showed differences in bird distribution in relation to the transect center line (observed number of differences > expected number of differences $P < 0.05$). In six tests, bird distribution in control transects were different between right and left side and six tests indicated that the number of individuals observed adjacent to the antenna was different than the number observed opposite the transect center. These results suggest that birds are not distributed randomly on control transects and therefore most likely not on treatment transects. Therefore, we cannot conclude that for those species (Nashville Warbler, Yellow-bellied Flycatcher, Chestnut-sided Warbler, Indigo Bunting) that had more individuals in the area adjacent to the antenna than on the opposite side that there is a positive effect of the edge on these species. More evidence is needed and will be gathered to determine if similar patterns are present in subsequent years and for all seasons. The Indigo Bunting will be especially monitored because it was the only species that had a strong tendency to occur in the area closest to the ROW edge and has been noted to be an "edge species" (Chasko and Gates 1982).

Observer Differences

Observer variability in bird detection and recording of birds observed is a potential source of error in bird census work (Kavanagh and Recher 1983). Several factors may contribute to variation in the ability to detect and record birds. They include: observer's hearing acuity (Cyr 1981; Ramsey and Scott 1981), avian density (Bart and Schoultz 1984), and ability to estimate distance to singing birds (Emlen and DeJong 1981; Scott et al. 1981). We considered potential effects that observer variation could have on results of this investigation when the study was designed (see methods). For example, observers census the same number of control and treatment segments in each census period and, although we estimate a distance to each bird observed, we do not presently use these values to calculate densities. We will compare distance values in future analyses to explore differences in observers to record distances.

Despite these controls for observer variability in our study design, we still were interested in identifying variability between observers that censused this year. Our test (an almost simultaneous census of 8 segments) was completed during the June breeding season when almost all bird observations are recorded by sound. Observer one started censusing 10 minutes before observer two (start time was offset to eliminate any affect that observers may have on each other) and observer one recorded more Ovenbirds than observer two. It is not clear what caused this difference between observers. It is unlikely that it was due to differences in hearing ability because the Ovenbird's song is loud, very distinct, and can easily be detected for > 100 m. It is more likely that the Ovenbird's singing behavior was affected by passage of the first observer, although we have no evidence to confirm this. We will conduct similar simultaneous censuses in which observer order will be reversed. This will allow us to determine

whether Ovenbird behavior is affected by the first observer or if differences actually exist between observers in their recording of Ovenbirds.

Analyses For Uncommon Species

Individual bird species analyzed with non-parametric tests were examined with three related but different data sets: frequency of species on control and treatment segments, total number of individuals observed on control and treatment segments, and a prominence value which is the product of the two. The prominence value can be viewed as a compromise between frequency of occurrence and number of individuals observed. Tests using the number of individuals observed produced the most significant results followed by prominence values and then frequency of occurrence. The number of significant tests is a function of the magnitude of the numbers used in the test. The number of individuals has the highest possible absolute values and frequencies the lowest.

Despite the inherent differences in these non-parametric tests, each data set has merit. Frequency of occurrence is the most conservative set because it is not biased by flocking or clustering of birds because the number of individuals observed is not included in the analysis. Number of individuals is the most liberal because it accounts for the numbers of individuals actually observed. One large flock of birds, however, could produce a significant result. The prominence value partially corrects for biases of flocking by integrating both frequency and number of individuals and this is why prominence values were used in summarizing results.

Although presenting results of all three data sets makes presentation of these data more complex, we will continue to present results for all three. This will allow us to take liberal, conservative, and a more

moderate approach to interpreting results of these data. More importantly, results of each test on a species is less important than detection of consistent pattern of an effect on a species. We contend that if there is an effect of the antenna system on a bird species, then this effect will most likely be identified and believable if the pattern is consistent over time.

Experimental Design - A Reevaluation

Each year we have attempted to reexamine our experimental design and the magnitude of differences we could detect with our sample size. In addition, this year we have included estimates for a paired design (Table 21). After completing the vegetation analyses in Wisconsin we plan to pair segments to produce a more powerful statistical design. We will also explore this possibility in Michigan. However, in Michigan we will be able to complete a before-and-after study which will provide us with a paired design. Finally, we are still entertaining the possibility of combining data for Michigan and Wisconsin which will allow us to double the sample size to 80 per treatment and control group.

Differences we estimate that can be detected for number of breeding species is about 14 to 17% for each state considered separately and about 10.5% if states are combined. A paired design, however, would reduce these percentages to about 11 to 14% for each state considered separately and to about 8.5% if the states are combined (Table 21). The latter figure achieves an absolute value of detection between control and treatment areas of about one individual per segment, which was our original goal for this study.

Table 21. Means, variances, and differences detectable with the sample sizes used in this study for a selected group of parameters. These data are presented in two sections: (a) using independent samples, and (b) using a paired design. Note that in the paired design we have assumed that 25% of the segments cannot be paired and, therefore, n is lower in the paired comparisons. Formulae used to determine detectable differences were the same as that used in Table 1, except now $d^2 = 15.8 \times s^2/n$ for the independent samples and $d^2 = 7.9 \times s^2/n$ for the paired design. (Snedecor and Cochran 1967).

Parameter per 500 m segment	State	Mean	Variance s^2	Difference detectable between means			
				n = 40		n = 80	
				Actual	%	Actual	%
A. Independent samples							
Number of species	Predicted	12.0	8.0	1.8	14.8	1.3	10.5
	Michigan	14.1	9.8	2.0	14.0	1.4	9.9
	Wisconsin	14.0	14.1	2.4	16.9	1.7	11.9
Number of individuals	Predicted	21.0	14.0	2.4	11.2	1.7	7.9
	Michigan	37.0	89.7	6.0	16.1	4.2	11.4
	Wisconsin	36.2	67.2	5.2	14.2	3.6	10.1
B. Paired design							
Number of species	Predicted	12.0	8.0	1.5	12.1	1.0	8.6
	Michigan	14.1	9.8	1.6	11.4	1.1	8.1
	Wisconsin	14.0	14.1	1.9	13.8	1.4	9.7
Number of individuals	Predicted	21.0	14.0	1.9	9.1	1.4	6.5
	Michigan	37.0	89.7	4.9	13.1	3.4	9.3
	Wisconsin	36.2	67.2	4.2	11.6	3.0	8.2

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Appendix 1. Nesting, feeding, habitat and migration classification
for bird species observed in Michigan and Wisconsin.

Appendix 1. Nesting, feeding, habitat, and migration classification for
bird species observed in Michigan and Wisconsin.

Species	Nesting	Food	Habitat	Migration
Common Loon	1	1	9,8	2
Pied-billed Grebe	1	1	9,8	2
American Bittern	3	1	6,9	2
Great Blue Heron	2	1	9,1,2,3	2
Wood Duck	4	18	9,1	2
Mallard	1	18	9,8	2
Blue-winged Teal	1	18	9,8	3,2
Turkey Vulture	1	3	3,1,5	2,3
Osprey	2	1	9,3	2,3
Bald Eagle	2	1	9,3	2,1
Northern Harrier	1	2	8,5,10	2,3
Sharp-shinned Hawk	2	2	2,3,11	2
Cooper's Hawk	2	2	1,3	2
Northern Goshawk	2	2	2,3	4,1
Broad-winged Hawk	2	2	3,1	
Red-tailed Hawk	2	2	5,1	
American Kestrel	4	2	5,4	
Spruce Grouse	1	4	2,11	
Ruffed Grouse	1	4	2,11	
Virginia Rail	3	11		
Sora	3	11,12		
Sandhill Crane	1			
Solitary Sandpiper	2,11			

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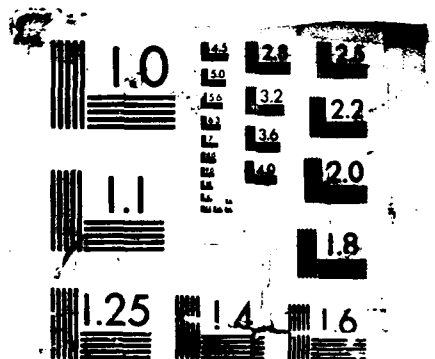
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Spotted Sandpiper	1	19	9	2,3
Common Snipe	1	19	8,6,5	2
American Woodcock	1	6	6,5,4,1	2
Mourning Dove	2,3	7	5,7	2
Black-billed Cuckoo	3	10	1,4,6	3
Yellow-billed Cuckoo	3	10	1,4,6	3
Great Horned Owl	2	2	3,2,1	1
Barred Owl	2	2	1,3	1
Common Nighthawk	1	11	3,7,4	3
Whip-poor-will	1	11	1,3,4	2
Chimney Swift	4	11	7,3,1	3
Ruby-throated Hummingbird	2	17	5,7,4	3
Belted Kingfisher	4	1	9	2
Yellow-bellied Sapsucker	4	17,16	1,3,2	2
Downy Woodpecker	4	16	1,4,3	1
Hairy Woodpecker	4	16	1,3,4	1
Black-backed Woodpecker	4	16	2,11,3	1
Northern Flicker	4	9	1,3,2	2
Pileated Woodpecker	4	16	1,3,2	1
Olive-sided Flycatcher	2	12	4,11,2	3
Eastern Wood-Pewee	2	12	3,1,2	3
Yellow-bellied Flycatcher	1	12	11,2	3
Alder Flycatcher	3	12	6	3
Least Flycatcher	2	12	1,3,4	3
Eastern Phoebe	5	12	9,7	2
Great Crested Flycatcher	4	12	1,3	3
Eastern Kingbird	2,3	12	5,4,10,8	3

Tree Swallow	4	11	5,7,4,9	2,3
Gray Jay	2	5	11,3,2	1
Blue Jay	2	5	1,3,2	1
American Crow	2	5	5,1,3,7	2,1
Common Raven	2	5	2,3,7	1
Black-capped Chickadee	4	10	1,3,11,2	1
Boreal Chickadee	4	10	11,2	1
Red-breasted Nuthatch	4	16	2,3,11,1	1
White-breasted Nuthatch	4	16	1,3	1
Brown Creeper	4	16	1,3,2,11	2,1
House Wren	4	10	7,4	2
Winter Wren	1,6	10	3,11,4,2	2
Sedge Wren	3	10	8,6,5	2
Marsh Wren	3	10	8	2
Golden-crowned Kinglet	2	10	2,11	2,1
Ruby-crowned Kinglet	2	10	2,11,4,6	2
Veery	1	9	1,4,3,6	3
Gray-cheeked Thrush	3	9	4,11,2	3
Swainson's Thrush	2,3	9	11,2,4	3
Hermit Thrush	1	9	3,11,1,2	2
Wood Thrush	3,1	9	1,3	3
American Robin	2,3,1	9	5,7,4,1	2,1
Gray Catbird	3	13	4,6,7	2,3
Brown Thrasher	3	9	4,7	2
Bohemian Waxwing	2	14	4,3,1	4
Cedar Waxwing	2	14	4,3,1	1,2
European Starling	4	9	7,3	1
Solitary Vireo	2	10	3,11,2	3,2

Yellow-throated Vireo	2	10	1,3	3
Warbling Vireo	2	10	4,3,1	3
Philadelphia Vireo	2,3	10	1,3,6	3
Red-eyed Vireo	2,3	10	1,3,4	3
Golden-winged Warbler	1,3	10	4,6	3
Tennessee Warbler	1	10	3,2,6,4	3
Orange-crowned Warbler	1	10	6,4,3	2,3
Nashville Warbler	1	10	3,4,11,2	3
Northern Parula	2	10	11,3,2	3
Yellow Warbler	3	10	6,5,7	3
Chestnut-sided Warbler	3	10	4,3	3
Magnolia Warbler	2,3	10	4,2,3	3
Cape May Warbler	2	10	2,3	3
Black-throated Blue Warbler	3	10	1,3,4	3
Yellow-rumped Warbler	2	13	2,3,11,4	2,3
Black-throated Green Warbler	2	10	3,1	3
Blackburnian Warbler	2	10	2,3	3
Pine Warbler	2	10	2	2
Palm Warbler	1	6	11,10	2,3
Bay-breasted Warbler	2	10	2,3	3
Blackpoll Warbler	2	10	2,4,3	3
Black-and-white Warbler	1	16	3,4,6,1	3
American Redstart	2,3	12,10	4,1,6	3
Ovenbird	1	6	1,3,2,4	3
Northern Waterthrush	1,6	6	9	3
Connecticut Warbler	1	10	11	3

Mourning Warbler	1,3	10	4,3	3
Common Yellowthroat	3	10	6,8,4	2,3
Wilson's Warbler	3	10	6	3
Canada Warbler	3	10	3,4	3
Scarlet Tanager	3	10	1,3	3
Rose-breasted Grosbeak	3,2	13	1,4,3	3
Indigo Bunting	3	15	5,4	3
Rufous-sided Towhee	1,2,3	8	4	2
American Tree Sparrow	3	7	5	4,2
Chipping Sparrow	2	8	2,3,4,11	2
Clay-colored Sparrow	3	8	5,6	2,3
Field Sparrow	1,3	8	5	2
Savannah Sparrow	1	8	5,8,10	2
Fox Sparrow	1,3	8	4,5	2
Song Sparrow	3	8	5,4,6	2
Lincoln's Sparrow	1	8	10,8,4	2
Swamp Sparrow	3	8	6,8	2
White-throated Sparrow	1	8	4,3,2,11,1	2
White-crowned Sparrow	1,3	8	4,6,5	2
Dark-eyed Junco	1	8	11,2,3,4	2,1
Snow Bunting	5	7	5	4
Bobolink	1	8	5,8	3
Red-winged Blackbird	3	8	8	2
Eastern Meadowlark	1	6	5	2
Western Meadowlark	1	6	5	2
Yellow-headed Blackbird	3	8	8	2
Rusty Blackbird	3	8	9	2
Brewer's Blackbird	3,1	8	5	2

Common Grackle	3	5	5,9,7	2
Brown-headed Cowbird	7	8	5,4,1,7	2
Northern Oriole	2	13	1,3	3
Pine Grosbeak	2	7	2,11	4
Purple Finch	2	7	3,2,4	2,1
Red Crossbill	2	7	2,11,3	4,1
White-winged Crossbill	2	7	2,11,3	4,1
Common Redpoll	3	7	5	4
Hoary Redpoll	3	7	5	4
Pine Siskin	2	15	2,3	1,4
American Goldfinch	3,2	7	5,6,4	2
Evening Grosbeak	2	15	3,2,7	1,4
House Sparrow	4	7	7	1

A. Nesting

- 1 Ground
- 2 Canopy or canopy vegetation (tree but not necessarily tree top)
- 3 Subcanopy or shrub
- 4 Cavity, hole or bank
- 5 Ledge or platform
- 6 Cavity - tree roots
- 7 Nest parasite

B. Food

- 1 Aquatic vertebrates, including species feeding on fish or other aquatic vertebrates
- 2 Predator on birds, small mammals, large insects

- 3 Scavenger
- 4 Species feeding on vegetation such as buds, pine needles, and seeds but excluding species concentrating on seeds or fruits
- 5 Omnivores; various small vertebrates (including eggs and young), invertebrates, plants, carrion, etc.
- 6 Ground invertebrates
- 7 Seeds (plus a smaller amount of fruit by some species)
- 8 Ground insects and seeds
- 9 Ground insects and fruit
- 10 Foliage insects
- 11 Aerial insects - taken while in continuous flight
- 12 Flycatchers
- 13 Foliage insects and fruit
- 14 Fruit
- 15 Foliage insects and seeds
- 16 Bark insects
- 17 Nectar and sap
- 18 Aquatic vegetation
- 19 Aquatic invertebrates

C. Habitat

- 1 Deciduous forest
- 2 Coniferous forest
- 3 Mixed deciduous - coniferous forest
- 4 Early successional deciduous - coniferous forest
- 5 Fields and meadows
- 6 Shrub swamp
- 7 Urban
- 8 Open wetlands (e.g., sedge fen, cattail)

- 9 Ponds, lakes, rivers, and streams
- 10 Muskeg
- 11 Lowland coniferous forest

D. Migration

- 1 Permanent resident; populations may be augmented during winter or during summer
- 2 Short-distance migrant; generally includes breeders; individuals generally winter south of study areas but most winter north of the tropics
- 3 Long-distance migrant; generally winter south of the U.S.
- 4 Winter resident

Appendix 2. Description of habitat variables used to quantify habitat characteristics of Wisconsin study areas.

Habitat Variable	Description
Ground Cover	Estimate of percent of green vegetation less than 10 cm in m ² surrounding the center point
Water Cover	Estimate of percent of standing water in m ² surrounding the center point
Water Depth	Depth at center point
Overall Height	Estimate of the average height of vegetation in 25 m ² surrounding center point
Tree Density	Density of trees greater than 2.5 cm diameter breast height (dbh) measured by the point-centered method
Tree Height	Height of four trees measured for tree density; measured with a clinometer
Tree Species	Identification of four trees measured for tree density
Tree Diameter	Measured dbh of four trees measured for tree density
Canopy Cover	Average of four readings taken with a spherical densiometer in NE quarter of point-centered plot
Log Density	Density of fallen logs greater than 2.5 cm diameter measured by the point-centered quarter method
Log Species	Identification of four logs measured for log density
Log Diameter	Measured diameter of four logs measured for log density. Diameter was measured at point where log was closest to center point.
Shrub Density	Density of shrubs greater than 30 cm and less than 2.5 cm dbh measured by the point-centered method. Shrubs were defined as any plant species that was persistent in the environment year round at a height of at least 30 cm (e.g., woody shrubs and cattails)
Shrub Height	Height of four shrubs measured for shrub density
Shrub Species	Species of four shrubs measured for shrub density
Forb Density	Density of forbs > 10 cm high measured by the point-centered method
Forb Species	Species of four forbs measured for forb density
Grass-Sedge Density	Density of grasses and sedges > 10 cm high measured by the point-centered method

Appendix 3. Description of habitat types used to classify Michigan study areas.

Appendix 3. Description of habitat types used to classify Michigan study areas.

Habitat Type	Description
Upland Conifer Forest	Upland forest with > 90% conifer species (e.g., pine)
Lowland Conifer Forest	Lowland forest with > 90% conifer species (e.g., black spruce)
Upland Deciduous Forest	Upland forest with > 90% mixed deciduous species
Maple Forest	Upland deciduous forest with > 90% maple species
Lowland Deciduous Forest	Lowland forest with > 90% deciduous species (e.g., black ash)
Upland Mixed Forest	Upland forest with mixed deciduous and coniferous species
Lowland Mixed Forest	Lowland forest with mixed deciduous and coniferous species
Cedar Forest	Lowland forest with > 90% cedar
Wet Shrub	Alder/willow wetland with no or few trees
Tree Shrub	Alder/willow wetland with trees (e.g., black ash or tamarack)
New Cut	Logged area < 5 years old
Young Cut Aspen	Logged area with aspen < 3m
Young Cut Mixed	Logged area with mixed species < 3m
Short Aspen	Logged area with aspen > 3m but < 10m
Short Mixed	Logged area with mixed species > 3m but < 10m
Open	Forest opening
Sedge	Wet sedge meadow
Pond	Small pond
Cattail	Wet area with > 90% cattail

Appendix 4a. Total number of individuals and species observed on control (C) and treatment (T) transects during five census periods in Michigan in 1986. English and scientific names follow AOU (1983, 1985).

Appendix 4a. Total number of individuals and species observed on control (C) and treatment (T) transects during five census periods in Michigan in 1986. English and scientific names follow AOU (1983, 1985).

	5-9 May		3-7 June		8-12 July		11-15 August		9-13 September	
	T	C	T	C	T	C	T	C	T	C
Great Blue Heron <u>Ardea herodias</u>	0	1			0	1				
Mallard <u>Anas platyrhynchos</u>	1	0	0	1			0	8	0	1
Broad-winged Hawk <u>Buteo platypterus</u>	0	1	0	1	3	3	4	2	1	1
Red-tailed Hawk <u>Buteo jamaicensis</u>					1	0	2	0		
American Kestrel <u>Falco sparverius</u>	1	0			1	0				
Spruce Grouse <u>Dendragapus canadensis</u>	1	0								
Ruffed Grouse <u>Bonasa umbellus</u>	9	7	8	1	2	26	3	7	13	18
Sandhill Crane <u>Grus canadensis</u>							1	0		
Solitary Sandpiper <u>Tringa solitaria</u>							0	2		
Common Snipe <u>Gallinago gallinago</u>					0	1				
American Woodcock <u>Scolopax minor</u>	2	0	1	2	1	6	1	0	3	0
Barred Owl <u>Strix varia</u>							1	0		
Common Nighthawk <u>Chordeiles minor</u>					0	1				
Whip-poor-will <u>Caprimulgus vociferus</u>	1	1			1	1				

Ruby-throated Hummingbird <u>Archilochus colubris</u>					1	0	1	3		
Belted Kingfisher <u>Ceryle alcyon</u>	0	1			0	3	1	0	0	1
Yellow-bellied Sapsucker <u>Sphyrapicus varius</u>	10	21	17	12	7	13	10	14	12	15
Downy Woodpecker <u>Picoides pubescens</u>	6	9	6	2	6	15	5	18	5	13
Hairy Woodpecker <u>Picoides villosus</u>	7	4	2	3	2	1	4	4	3	6
Black-backed Woodpecker <u>Picoides arcticus</u>	0	1			1	0	1	4	2	2
Northern Flicker <u>Colaptes auratus</u>	23	31	6	8	26	27	12	9	12	12
Pileated Woodpecker <u>Dryocopus pileatus</u>	1	0			0	2	2	4	0	1
Olive-sided Flycatcher <u>Contopus borealis</u>	1	0	0	1	5	0				
Eastern Wood-Pewee <u>Contopus virens</u>			5	11	6	13	12	13	0	4
Yellow-bellied Flycatcher <u>Empidonax flaviventris</u>			33	14	12	5	1	4		
Alder Flycatcher <u>Empidonax alnorum</u>			7	10	5	2				
Least Flycatcher <u>Empidonax ustulatus</u>	16	42	26	69	2	17				
Eastern Phoebe <u>Sayornis phoebe</u>	1	1	0	1			2	0	0	1
Great Crested Flycatcher <u>Myiarchus crinitus</u>	4	6	9	19	8	12	1	3	1	0
Eastern Kingbird <u>Tyrannus tyrannus</u>	0	2	3	1	6	7	5	0		
Tree Swallow <u>Tachycineta bicolor</u>	0	11	1	1						
Gray Jay <u>Perisoreus canadensis</u>			1	0			5	0	5	10

Blue Jay <u>Cyanocitta cristata</u>	53	58	28	13	17	18	22	16	19	37
American Crow <u>Corvus brachyrhynchos</u>	0	2	4	0	8	0	1	1	0	1
Common Raven <u>Corvus corax</u>	0	2	0	1	1	4	1	3	0	5
Black-capped Chickadee <u>Parus atricapillus</u>	23	26	9	9	48	59	45	32	68	122
Boreal Chickadee <u>Parus hudsonicus</u>	5	0	2	0	5	0	3	0		
Red-breasted Nuthatch <u>Sitta canadensis</u>	11	8	8	2	8	7	18	12	14	19
White-breasted Nuthatch <u>Sitta carolinensis</u>	3	4	0	1	0	5	1	3	3	3
Brown Creeper <u>Certhia americana</u>	2	10	0	3	4	8	2	7	4	16
Winter Wren <u>Troglodytes troglodytes</u>	15	32	9	21	17	16	0	3	1	7
Sedge Wren <u>Cistothorus platensis</u>	1	6	5	5	4	3	2	1		
Golden-crowned Kinglet <u>Regulus satrapa</u>	42	20	26	19	47	24	38	31	57	55
Ruby-crowned Kinglet <u>Regulus calendula</u>	10	8	1	6					1	6
Veery <u>Catharus fuscescens</u>			24	19	8	11	0	2		
Gray-cheeked Thrush - <u>Catharus minimus</u>									1	1
Swainson's Thrush <u>Catharus ustulatus</u>					0	1			2	4
Hermit Thrush <u>Catharus guttatus</u>	19	26	10	16	78	44	4	5	19	21
Wood Thrush <u>Hylocichla ustelina</u>	1	1	4	4						
American Robin <u>Turdus migratorius</u>	38	42	23	30	29	22	9	7	7	7

Gray Catbird <u>Dumetella carolinensis</u>			0	1						
Brown Thrasher <u>Toxostoma rufum</u>	5	1	5	0				1	0	
Cedar Waxwing <u>Bombycilla cedrorum</u>	0	1	8	11	4	0	7	14	0	2
European Starling <u>Sturnus vulgaris</u>	0	3	0	2	0	1				
Solitary Vireo <u>Vireo solitarius</u>	6	2			3	6				
Yellow-throated Vireo <u>Vireo flavifrons</u>	0	1			0	2				
Warbling Vireo <u>Vireo gilvus</u>			0	2						
Philadelphia Vireo <u>Vireo philadelphicus</u>			0	1						
Red-eyed Vireo <u>Vireo olivaceus</u>	8	8	98	99	76	116	15	17	0	5
Golden-winged Warbler <u>Vermivora chrysoptera</u>	3	10	7	5						
Tennessee Warbler <u>Vermivora peregrina</u>	0	2	1	2					5	13
Nashville Warbler <u>Vermivora ruficapilla</u>	215	208	136	65	81	26	8	6	0	19
Northern Parula <u>Parula americana</u>	0	10	8	18	0	2				
Yellow Warbler <u>Dendroica petechia</u>					1	0				
Chestnut-sided Warbler <u>Dendroica pensylvanica</u>	7	12	68	50	23	17	1	2	0	1
Magnolia Warbler <u>Dendroica magnolia</u>	2	10	1	3	0	1	1	0	0	3
Cape May Warbler <u>Dendroica tigrina</u>	0	5	1	7			2	0		
Black-throated Blue Warbler <u>Dendroica caerulescens</u>	0	2			1	1	3	0		

Yellow-rumped Warbler <u>Dendroica coronata</u>	62	37	19	3	11	14	3	8	17	34
Black-throated Green Warbler <u>Dendroica virens</u>	75	97	54	66	40	57	1	8	0	3
Blackburnian Warbler <u>Dendroica fusca</u>			6	8	3	3	3	5	0	1
Pine Warbler <u>Dendroica pinus</u>	0	1								
Palm Warbler <u>Dendroica palmarum</u>	6	4							1	6
Bay-breasted Warbler <u>Dendroica castanea</u>			0	2			0	2	4	2
Black-and-white Warbler <u>Mniotilta varia</u>	17	34	20	25	0	5	4	3	0	2
American Redstart <u>Setophaga ruticilla</u>			2	0	1	0	1	1	0	19
Ovenbird <u>Seiurus aurocapillus</u>	55	100	177	199	106	108	10	12	8	21
Northern Waterthrush <u>Seiurus noveboracensis</u>	0	5	1	1						
Connecticut Warbler <u>Oporornis agilis</u>	0	1	3	1	3	0				
Mourning Warbler <u>Oporornis philadelphia</u>	1	1	18	17	6	5	5	2		
Common Yellowthroat <u>Geothlypis trichas</u>	3	1	6	30	8	26	0	1	2	10
Canada Warbler <u>Wilsonia canadensis</u>			2	3	1	6	1	2		
Scarlet Tanager <u>Piranga olivacea</u>	1	1	6	13	3	4	1	0	1	0
Rose-breasted Grosbeak <u>Phoebastria ludovicianus</u>	2	36	33	56	5	6			0	4
Indigo Bunting <u>Passerina cyanea</u>			10	9	14	16	0	1		
Rufous-sided Towhee <u>Pipilo erythrophthalmus</u>	5	3	4	5	4	6	0	3	1	0

Chipping Sparrow <u>Spizella passerina</u>	11	30	13	13	16	14	1	0	4	0
Song Sparrow <u>Melospiza melodia</u>	5	7	7	18	11	21	2	8	1	0
Lincoln's Sparrow <u>Melospiza lincolni</u>			1	0	0	2			0	1
Swamp Sparrow <u>Melospiza georgiana</u>	18	11	4	5	15	23	1	0	3	8
White-throated Sparrow <u>Zonotrichia albicollis</u>	85	55	60	33	74	50	23	22	36	19
Dark-eyed Junco <u>Junco hyemalis</u>	0	1			0	2			0	1
Red-winged Blackbird <u>Agelaius phoeniceus</u>	0	41	2	34	5	2				
Common Grackle <u>Quiscalus quiscula</u>	1	5	0	14	0	2				
Brown-headed Cowbird <u>Molothrus ater</u>	8	20	1	10	1	0				
Northern Oriole <u>Icterus galbula</u>	0	4	0	3						
Purple Finch <u>Carpodacus purpureus</u>	13	18	8	7	0	2				
Pine Siskin <u>Carduelis pinus</u>	0	1								
American Goldfinch <u>Carduelis tristis</u>	2	6			5	2	6	7	2	2
Evening Grosbeak <u>Coccothraustes vespertinus</u>	2	7								
Unidentified passerine bird	24	24	25	20	45	52	59	82	62	65
Unidentified woodpecker			5	2	2	0	2	4	1	6
Total Individuals	949	1210	1098	1169	938	978	380	478	432	627
Total Species	54	69	60	68	59	63	53	46	36	48

Appendix 4b. Total number of individuals and species observed on control (C) and treatment (T) transects in Wisconsin during five census periods in 1986. English and scientific names follow AOU (1983, 1985).

Appendix 4b. Total number of individuals and species observed on control (C) and treatment (T) transects in Wisconsin during five census periods in 1986. English and scientific names follow AOU (1983, 1985).

	15-19 May		14-20 June		20-24 July		24-28 August		19-24 September	
	T	C	T	C	T	C	T	C	T	C
Common Loon <u>Gavia immer</u>					0	1	1	0		
Pied-billed Grebe <u>Podilymbus podiceps</u>									0	2
American Bittern <u>Botaurus lentiginosus</u>	2	0								
Great Blue Heron <u>Ardea herodias</u>									0	1
Wood Duck <u>Aix sponsa</u>	1	0							0	3
Sharp-shinned Hawk <u>Accipiter striatus</u>									0	1
Broad-winged Hawk <u>Buteo platypterus</u>	2	0	2	2	0	4	2	0		
Spruce Grouse <u>Dendragapus canadensis</u>					0	1				
Ruffed Grouse <u>Bonasa umbellus</u>	17	17	3	3	8	16	7	7	6	21
Common Snipe <u>Gallinago gallinago</u>	4	0	1	0						
American Woodcock <u>Scelopax minor</u>			1	0	0	1	0	1	0	1
Barred Owl <u>Strix varia</u>			2	0	0	3			0	1
Ruby-throated Hummingbird <u>Archilochus colubris</u>			1	0						
Belted Kingfisher <u>Ceryle alcyon</u>					0	1			0	1

Yellow-bellied Sapsucker <u>Sphyrapicus varius</u>	11	9	12	15	11	9	2	9	7	10
Downy Woodpecker <u>Picoides pubescens</u>	1	0	2	6	4	3	4	8	9	13
Hairy Woodpecker <u>Picoides villosus</u>	1	2	8	4	0	5	2	3	5	3
Northern Flicker <u>Colaptes auratus</u>	9	11	4	5	16	17	6	5	4	4
Pileated Woodpecker <u>Dryocopus pileatus</u>	0	2	2	0			1	1	2	0
Olive-sided Flycatcher <u>Contopus borealis</u>			3	0	1	4				
Eastern Wood-Pewee <u>Contopus virens</u>	1	1	2	10	6	14	0	4	0	1
Yellow-bellied Flycatcher <u>Empidonax flaviventris</u>	10	7	31	23	20	22				
Alder Flycatcher <u>Empidonax alnorum</u>			9	4	15	0	0	2		
Least Flycatcher <u>Empidonax ustulatus</u>	21	51	18	25			0	1		
Eastern Phoebe <u>Sayornis phoebe</u>	0	1								
Great Crested Flycatcher <u>Myiarchus crinitus</u>	1	3	3	15	4	3				
Eastern Kingbird <u>Tyrannus tyrannus</u>	0	2	0	1	1	1	2	0		
Tree Swallow <u>Tachycineta bicolor</u>	1	0								
Gray Jay <u>Perisoreus canadensis</u>	1	3	2	2	3	2	3	2	5	1
Blue Jay <u>Cyanocitta cristata</u>	48	44	30	22	15	38	35	29	15	17
American Crow <u>Corvus brachyrhynchos</u>	1	2			1	0	2	0	8	0
Common Raven <u>Corvus corax</u>	4	0			1	0	1	0	2	1

Black-capped Chickadee <u>Parus atricapillus</u>	15	13	16	15	58	67	65	90	136	131
Boreal Chickadee <u>Parus hudsonicus</u>	0	2			9	4	3	1	4	1
Red-breasted Nuthatch <u>Sitta canadensis</u>	8	6	0	3	26	15	23	19	62	54
White-breasted Nuthatch <u>Sitta carolinensis</u>	0	2	1	0	0	3	1	3	0	7
Brown Creeper <u>Certhia americana</u>	1	2	4	4	4	4	12	20	6	11
Winter Wren <u>Troglodytes troglodytes</u>	22	21	30	23	25	29	4	6	3	5
Sedge Wren <u>Cistothorus platensis</u>	6	0	2	0	9	0	2	0	3	0
Golden-crowned Kinglet <u>Regulus satrapa</u>	23	15	35	14	45	22	54	35	33	37
Ruby-crowned Kinglet <u>Regulus calendula</u>	1	0	2	0					18	8
Veery <u>Catharus fuscescens</u>	2	2	4	21	0	1				
Gray-cheeked Thrush <u>Catharus minimus</u>									0	2
Swainson's Thrush <u>Catharus ustulatus</u>									0	1
Hermit Thrush <u>Catharus guttatus</u>	17	22	40	26	58	45	13	4	13	8
Wood Thrush <u>Hylocichla ustelina</u>	17	17	1	0						
American Robin <u>Turdus migratorius</u>	31	23	15	7	8	5	6	3	18	10
Gray Catbird <u>Dumetella carolinensis</u>	1	1	1	1						
Brown Thrasher <u>Toxostoma rufum</u>	2	1								
Cedar Waxwing <u>Bombycilla cedrorum</u>			2	1	7	4	0	1		

European Starling <u>Sturnus vulgaris</u>	0	1								
Solitary Vireo <u>Vireo solitarius</u>	4	5	0	1	1	1				
Yellow-throated Vireo <u>Vireo flavifrons</u>	1	0	0	1	3	1				
Warbling Vireo <u>Vireo gilvus</u>	0	1								
Philadelphia Vireo <u>Vireo philadelphicus</u>	1	0								
Red-eyed Vireo <u>Vireo olivaceus</u>	67	70	94	103	127	121	18	27	1	0
Golden-winged Warbler <u>Vermivora chrysoptera</u>	5	8	5	1						
Tennessee Warbler <u>Vermivora peregrina</u>	21	27							1	0
Nashville Warbler <u>Vermivora ruficapilla</u>	242	244	123	105	12	10	21	5	1	0
Northern Parula <u>Parula americana</u>	10	43	16	22						
Yellow Warbler <u>Dendroica petechia</u>	3	0	2	1						
Chestnut-sided Warbler <u>Dendroica pensylvanica</u>	81	65	71	56	10	4	4	5		
Magnolia Warbler <u>Dendroica magnolia</u>	9	1	1	1	2	0			0	1
Cape May Warbler <u>Dendroica tigrina</u>	16	2	5	1						
Black-throated Blue Warbler <u>Dendroica caerulescens</u>			0	1					0	1
Yellow-rumped Warbler <u>Dendroica coronata</u>	31	19	8	3	15	4	26	24	196	101
Black-throated Green Warbler <u>Dendroica virens</u>	79	96	56	39	29	27	6	12	3	6
Blackburnian Warbler <u>Dendroica fusca</u>	10	13	23	21	2	1				

Pine Warbler <u>Dendroica pinus</u>	1	1	2	2						
Pala Warbler <u>Dendroica palmarum</u>	8	2	4	0		5	0	27	4	
Bay-breasted Warbler <u>Dendroica castanea</u>						1	0			
Blackpoll Warbler <u>Dendroica striata</u>	0	5								
Black-and-white Warbler <u>Mniotilta varia</u>	39	74	25	25	9	3	2	2		
American Redstart <u>Setophaga ruticilla</u>			1	2			3	2		
Ovenbird <u>Seiurus aurocapillus</u>	192	251	175	191	15	33	45	35	0	2
Northern Waterthrush <u>Seiurus noveboracensis</u>	3	2	0	2	0	2			0	1
Connecticut Warbler <u>Oporornis agilis</u>	0	6	3	0	0	1				
Mourning Warbler <u>Oporornis philadelphia</u>	8	8	21	17	4	4				
Common Yellowthroat <u>Geothlypis trichas</u>	40	27	23	13	33	23	10	4	4	0
Canada Warbler <u>Wilsonia canadensis</u>	11	2	9	23	6	6	7	1		
Scarlet Tanager <u>Piranga olivacea</u>	12	6	9	8	1	1				
Rose-breasted Grosbeak <u>Pheucticus ludovicianus</u>	5	26	8	24	1	0	0	1		
Indigo Bunting <u>Passerina cyanea</u>	3	0	14	1	0	1				
Rufous-sided Towhee <u>Pipilo erythrophthalmus</u>					1	0				
Chipping Sparrow <u>Spizella passerina</u>	15	12	28	5	6	2	1	0		
Savannah Sparrow <u>Passerculus sandwichensis</u>	0	2								

Song Sparrow <u>Melospiza melodia</u>	21	9	19	16	17	15	3	1	2	0
Lincoln's Sparrow <u>Melospiza lincolni</u>	5	0	4	0	4	0				
Swamp Sparrow <u>Melospiza georgiana</u>	10	0	17	2	22	3	6	3	11	0
White-throated Sparrow <u>Zonotrichia albicollis</u>	94	80	100	78	72	115	25	41	44	71
Dark-eyed Junco <u>Junco hyemalis</u>					6	0	0	3	6	7
Red-winged Blackbird <u>Agelaius phoeniceus</u>	9	7	8	0	0	3				
Common Grackle <u>Quiscalus quiscula</u>	0	2	1	8	1	0				
Brown-headed Cowbird <u>Molothrus ater</u>	3	1	2	1						
Northern Oriole <u>Icterus galbula</u>			1	0	0	2				
Purple Finch <u>Carpodacus purpureus</u>	8	8	5	2	0	2			0	3
American Goldfinch <u>Carduelis tristis</u>	3	0	1	1	9	5	10	1	0	5
Evening Grosbeak <u>Coccothraustes vespertinus</u>	4	6			1	0				
Unidentified passerine bird	36	35	34	17	91	70	75	47	22	75
Unidentified woodpecker	1	3	0	3	3	4	3	9	5	11
Total Individuals	1396	1452	1207	1050	858	808	522	477	682	644
Total Species	67	62	66	57	50	54	40	38	31	39

Appendix 5. Tree (A), shrub (B), and forb (C) species identified on Wisconsin study areas measured with the quantitative vegetation method. Nomenclature from Lakela (1965).

Appendix 5. Tree (A), shrub (B), and forb (C) species identified on Wisconsin study areas measured with the quantitative vegetation method. Nomenclature from Lakela (1965).

A. TREES

White Pine
Pinus strobus

Red Pine
P. resinosa

Jack Pine
P. banksiana

Tamarack
Larix laricina

Balsam Fir
Abies balsamea

Hemlock
Tsuga canadensis

White Spruce
Picea glauca

Black Spruce
P. mariana

Northern White Cedar
Thuja occidentalis

Quaking Aspen
Populus tremuloides

Large-toothed Aspen
P. grandidentata

Balsam Poplar
P. balsamifera

Butternut
Juglans cinerea

Ironwood
Ostrya virginiana

Paper Birch
Betula papyrifera

Yellow Birch
B. lutea

Red Oak
Quercus rubra

Bur Oak
Q. macrocarpa

Black Cherry
Prunus serotina

Red Maple
Acer rubrum

Sugar Maple
Acer saccharum

Basswood
Tilia americana

Green Ash
Fraxinus pennsylvanica

Black Ash
F. nigra

Elm
Ulmus spp.

B. SHRUBS

White Pine
Pinus strobus

Red Pine
P. resinosa

Jack Pine
P. banksiana

Tamarack
Larix laricina

Balsam Fir
Abies balsamea

Hemlock
Tsuga canadensis

White Spruce
Picea glauca

Black Spruce
P. mariana

Northern White Cedar
Thuja occidentalis

Cattail
Typha latifolia

Willow
Salix spp.

Quaking Aspen
Populus tremuloides

Large-toothed Aspen
P. granidentata

Balsam Poplar
P. balsamifera

Sweet Gale
Myrica gale

Butternut
Juglans cinerea

Hazel
Corylus spp.

Ironwood
Ostrya virginiana

Paper Birch
Betula papyrifera

Yellow Birch
B. lutea

Dwarf Birch
B. pumila

Alder
Alnus spp.

Red Oak
Quercus rubra

Bur Oak
Q. macrocarpa

Gooseberry
Ribes spp.

Thimbleberry
Rubus parviflorus

Raspberry
Rubus strigosus

Blackberry
R. allegheniensis

Black Cherry
Prunus serotina

Choke Cherry
P. virginiana

Pincherry
P. pensylvanica

Meadow Sweet
Spiraea alba

Juneberry
Amelanchier spp.

Mountain Ash
Pyrus americana

Red Maple
Acer rubrum

Mountain Maple
Acer spicatum

Sugar Maple
Acer saccharum

Basswood
Tilia americana

Leatherwood
Dirca palustris

Dogwood
Cornus spp.

Green Ash
Fraxinus pennsylvanica

Black Ash
Fraxinus nigra

C. FORBS

Equisetum
Equisetum spp.

Lycopodium
Lycopodium spp.

Grape Fern
Botrychium virginianum

Interrupted Fern
Osmunda Claytoniana

Cinnamon Fern
O. cinnamonnea

Ostrich Fern
Matteuccia struthiopteris

Sensitive Fern
Onoclea sensibilis

Shield Fern
Dryopteris spp.

Oak Fern
Dryopteris disjuncta

Beech Fern
Thelypteris Phegopteris

Lady Fern
Athyrium Filix-femina

Bush Honeysuckle
Diervilla lonicera

Fly Honeysuckle
Lonicera canadensis

Arrowwood
Viburnum spp.

Red Elderberry
Sambucus pubens

Elm
Ulmus spp.

Maidenhair Fern
Adiantum pedatum

Bracken Fern
Pteridium aquilinum

Jack-in-the-Pulpit
Arisaema atrorubens

Wild Calla
Calla palustris

Leek
Allium tricoccum

Bluebead Lily
Clintonia borealis

Trillium
Trillium spp.

Mayflower
Maianthemum canadense

3-Leaved False Solomon's Seal
Smilacina trifolia

Twisted Stalk
Streptopus spp.

Wild Iris
Iris versicolor

Orchids <u>Orchidaceae</u> Family	Poison Ivy <u>Rhus radicans</u>
Sweet Fern <u>Comptonia peregrina</u>	Impatients <u>Impatiens</u> spp.
Stinging Nettle <u>Parietaria</u> spp.	St. John's Wort <u>Hypericum</u> spp.
Ginger <u>Asarum canadense</u>	Violet Spp. <u>Viola</u> spp.
Swamp Smartweed <u>Polygonum</u> spp.	Sarsaparilla <u>Aralia nudicaulis</u>
Arrowleaf Tear Thumb <u>Polygonum sagittatum</u>	Cow Parsnip <u>Heracleum lanatum</u>
Fringed Bindweed <u>P. cilinode</u>	Sweet Cicely <u>Osmorhiza claytoni</u>
Gold Thread <u>Coptis groenlandica</u>	Water Hemlock <u>Cicuta bulbifera</u>
Baneberry <u>Actaea rubra</u>	Bunchberry <u>Cornus canadensis</u>
Marsh Marigold <u>Caltha palustris</u>	Wintergreen <u>Gaultheria procumbens</u>
Hepatica <u>Hepatica americana</u>	Labrador Tea <u>Ledum groenlandicum</u>
Anemone <u>Anemone</u> spp.	Bog Laurel <u>Kalmia polifolia</u>
Blue Cohosh <u>Caulophyllum thalictroides</u>	Bog Rosemary <u>Andromeda glaucophylla</u>
Strawberry <u>Fragaria</u> spp.	Leatherleaf <u>Chamaedaphne calyculata</u>
Bloodroot <u>Sanquinaria canadensis</u>	Bear Berry <u>Arctostaphylos uva-ursi</u>
Potentilla <u>Potentilla</u> spp.	Blueberry <u>Vaccinium</u> spp.
Rubus Spp. <u>Rubus</u> spp.	Cranberry <u>Vaccinium</u> spp.
Clover <u>Trifolium</u> spp.	Loosestrife <u>Lysimachia</u> spp.

Star Flower
Trientalis borealis

Spreading Dogbane
Apocynum androsaemifolium

Mint Spp.
Lamiaceae Family

Mullein
Verbascum spp.

Marsh Speedwell
Veronica scutellata

Plantain
Plantago spp.

Bedstraw
Galium spp.

Composite
Asteraceae Family

Joe-Pye-Weed
Eupatorium maculatum

Goldenrod
Solidago spp.

Aster Spp.
Aster spp.

Large-Leaved Aster
Aster macrophyllus

Pearly Everlasting
Anaphalis margaritacea

Coltsfoot
Petasites palmatus

Dandelion
Taraxacum officinale

Appendix 6. Species showing significant differences during June 1985 between control and treatment transects. Species were examined for differences in number of control (C) and treatment (T) transects the species occurred, in total number of individuals recorded on control and treatment transects, and in prominence value (see text) for that species on control and treatment transects. Species are included only if they occurred on at least 6 control or treatment transects. Differences are tested with a G-test or with a Fisher Exact test when $N=0$ (Sokal and Rohlf 1981).

Appendix 6. Species showing significant differences during June 1985 between control and treatment transects. Species were examined for differences in number of control (C) and treatment (T) transects the species occurred, in total number of individuals recorded on control and treatment transects, and in prominence value (see text) for that species on control and treatment transects. Species are included only if they occurred on at least 6 control or treatment transects. Differences are tested with a G-test or with a Fisher Exact test when $N=0$ (Sokal and Rohlf 1981).

Species	Michigan						Wisconsin					
	Transect		Individual		PV		Transect		Individual		PV	
	T	C	T	C	T	C	T	C	T	C	T	C
Buffed Grouse							2	6	2 **	13	0.4 *	5.0
Eastern Wood-Pewee	13	7	18 *	8	10.3	3.3						
Yellow-bellied Flycatcher	14	6	44 ***	6	26.0 ***	2.3						
Alder Flycatcher							9	4	25 **	8	11.6 *	2.5
Great-crested Flycatcher							22	17	16 **	38	11.9 *	24.8
Winter Wren	6	15	8 **	23	3.1 **	14.1	6 *	15	8 ***	32	3.1 ***	19.6
Golden-crowned Kinglet	11 *	3	26 ***	3	13.6 ***	0.8						
Veery							3	9	4 *	13	1.1	6.2
American Robin	19	17	41 *	21	28.3 *	13.7	23 ***	5	38 ***	10	28.8 ***	3.5
Northern Parula	1	6	1 **	9	0.2	3.5						
Yellow-rumped Warbler	10	3	19 ***	3	9.5 **	0.8	10	4	19 *	7	9.5 *	2.2
Canada Warbler							2	8	2 *	9	0.4	4.0
Indigo Bunting	1 *	7	1 *	7	0.2	2.9						
Chipping Sparrow	9	3	18 **	4	8.5 *	1.1	12 *	4	19 **	5	10.4 **	1.6
Song Sparrow	3	7	4 *	19	1.1 *	7.9						
Swamp Sparrow							6	2	13 ***	1	5.0 *	0.2
Evening Grosbeak							9 **	1	12 **	1	5.7 *	0.2

* = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$

END

10-81

DTIC